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EDITORIAL

The first issue of OUTLOOK ON AGRICULTURE has been welcomed everywhere, and this strengthens our belief that there is room for a journal of its kind despite the voluminous literature on agriculture and related sciences. At least three-quarters of the periodicals now received in technical libraries came into being after 1920, and their numbers have been rising by about 5% each year. In consequence it has become increasingly hard for the research worker to keep up to date even in his own specialized field, and he has little time to spare for wider reading. It will be our aim in this journal to help to overcome the difficulty by providing reviews on subjects of topical interest and by ensuring that all matter in its pages will be easy to read and to digest.

Progress in Lalang Control

Events in the field of plant protection move with great rapidity. Since our article on lalang control went to press, a brief report in the Planters' Bulletin of the Rubber Research Institute of Malaya (No. 23, pp. 27–8) has announced highly successful results with a new herbicide called dalapon, this being the sodium salt of 2,2-dichloropropionic acid. In small-scale trials in 1955 dalapon was found to be unusually effective for the control of various grasses, giving 95–100% kills at rates of 10–25 lb./acre and preventing recolonization for several months. Spraying 15 lb./acre twice a year was enough to control grasses in young rubber, and once a year in mature rubber. Dalapon was also found to kill lalang more effectively than sodium arsenite or STCA, but optimum rates have not yet been determined. No harm was done to 7-year-old rubber trees by two doses at 50 lb./acre or to young rubber at 25 lb./acre. Laboratory tests showed that the chemical is actively absorbed by grass foliage and roots and translocated within the plant. It disappears from the soil fairly rapidly. Toxicity to animals is not high.

Prospects of the Cacao Grower

Prospects of the cacao grower are perhaps less happy than they seemed to be a few years ago. U.K. prices for dry cocoa were around £75 a ton in 1945, and after sugar rationing came to an end they soared to a peak of £560 a ton in 1954. This proved high enough to check demand, and prices have since fallen to little more than £200. It is characteristic of the crop that seasonal influences and the prevalence of disease greatly affect output, so that fairly wide fluctuations in prices from year to year are to be expected, but it is doubtful if the high figure quoted will ever be reached again.

The view has been expressed that world consumption might rise to an annual 1 million tons of dry cocoa. This could be met by an increase in output of only 25%. As efforts are being made to expand production the state of undersupply is not likely to last indefinitely, and growers may eventually have to face less favourable prices for their crops. So long as the upward trend prevailed, cacao growing was expanded without much thought for the future. It is now possible that more attention will have to be paid to elimination of diseases, the cultivation of high-yielding clones, and other methods of increasing output and lowering costs of production per acre. There is, moreover, the hazard to existing growers of expansion of the crop to other lands in the hope of securing disease-free crops. Already large-scale trials in Malaya have shown that cacao can be brought to bearing in four years as against five years in Trinidad using clonal material and ten years or more under conditions in West Africa.

Books on Rice Production

It is a remarkable fact that although rice is one of the most important crops in the world, students of agriculture have had to rely almost entirely on technical journals for information on its production. Indeed, the only book on the subject in the English language seems to have been Copeland's well-known work issued thirty-two years ago, until D. H. Grist's *Rice* was published in 1953. The position is fast being remedied. At least three other books in English have now appeared; two of these are reviewed on pages 79–80 of this journal; the other, called *Means of increasing Rice Production*, is by J. G. de Geus (Centre d'Etude de l'Azote, Geneva, 1954, pp. 143), and it stresses the possibility of increasing rice yields by the efficient use of fertilizers in all the main rice-growing lands.

A few useful foreign works have also been published. *Le Riz* by Y. Coyaud (Archives de l'Office Indochinois du Riz, 1950, No. 30, pp. 312) is a treatise dealing in detail with botanical, genetical and ecological features of the plant and cultural methods and conditions of production in Indo-China. *Le Riz dans l'Economie Egyptienne* (Société d'Enterprises Commerciales en Egypte, 1949, pp. 67) is concerned exclusively with the importance and culture of rice in Egypt. Two brochures published in 1954 and 1955 by the Ruhr-Stickstoff A.G., Bochum, describe rice culture and manuring in East Asia and in other countries.

FERTILIZER PLACEMENT

G. W. Cooke

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Within the past ten years experimental work in Great Britain, mostly by the author and his colleagues at Rothamsted, has established methods for the placement of fertilizers that frequently give better results than broadcasting. This paper assesses the value of these techniques for most of our common crops, discusses the factors involved, and suggests how the British work might be applied to cultural conditions in other lands.

Fertilizers must be applied to the soil in such a way that they can be reached by the roots of crops. When broadcast, they may be mixed with the soil by cultivations, and soluble materials applied on the surface will be washed in by rain; in either case dressings are dispersed in a considerable bulk of soil. In contrast, fertilizers may be concentrated in pockets or in continuous narrow bands, close to the seed at sowing time or beside the rows of established crops; this method, called "placement," is less wasteful and frequently more effective than broadcasting.

Placement is not a new idea. Very old records show that North American Indians placed fish with the seed of maize grown in hills. English writers of the seventeenth century described drills which were intended to sow manure and seed, though it is doubtful if these machines were ever constructed or worked satisfactorily. In experiments on turnips during the 1840s J. B. Lawes [13], the founder of Rothamsted, drilled his newly discovered fertilizers with the seed and obtained good results from superphosphate, but nitrogenous fertilizers used in this way were apt to damage germination. Later in the last century distributors were developed in England to spread fertilizers uniformly over the surface of the soil and they became very popular, yet for more than eighty years after chemical fertilizers were introduced the only placement machines were rather primitive root-crop drills used in the Fenland and in a few other restricted areas. In America and other countries, however, where large areas of land had to be sown as quickly as possible, "combine-drills" were developed to sow cereal seed and apply fertilizers in one operation. These machines were ideal for applying small dressings of superphosphate, essential to secure a crop in dry areas. For crops other than cereals, damage to germination was often caused by drilling fertilizer with the seed; but it was found that injury could be avoided by separating seed and fertilizer by a layer of soil, and after extensive research in the United States drills were developed which place a band of fertilizer an inch or so to the side of the seed and a little below its level.

Although a few farmers in England continued to mix seed and fertilizer and sow in the ordinary drill, placement was little used in this country until combine-drills were imported just before the 1939–45 war. British research on the value of placement methods started about this time, and knowledge of the subject has been summarized by Miles [14] to the end of 1946; but much experimental work has been done since then, and it is now possible to define the use of special methods of applying fertilizers for our common crops.

The purpose of this paper is to review recent work on placement, and to assess the value of the technique under British conditions. When the results of applied research are incorporated into ordinary farm practice, gains from special methods must be expressed on a monetary basis as well as on the basis of extra yields; a few statements of cash gains at 1956 prices are therefore given here in the hope that they may help to put possible benefits from recommended new practices into perspective for farmers and their advisers. Since placement methods have been developed by empirical experimentation and the benefits obtained depend on the crop grown, on the kind of soil, and on the climate, a few simple principles are set out at the end of this paper to explain the effects of placement and suggest how work in Britain can be applied to other cultural conditions.

The results of placement research in other countries were reviewed by Cooke and Widdowson in 1955 [9]. Recommendations made for British crops on the basis of experiments carried out in this country agree, broadly, with the findings of American workers. Where results obtained in the two countries differ, the reason is usually that soils, climatic conditions, or cultural practices are so different that agreement cannot be expected.

CEREALS

Experiments testing the value of combine-drilling fertilizers for cereals, summarized by Crowther in 1945 [11], showed that combine-drilled dressings of superphosphate gave higher yields than equivalent broadcast dressings; on average, 1·5 cwt. of superphosphate per acre applied by combine-drill was as effective as 3 cwt./acre broadcast over the seedbed. Similar benefits were obtained with muriate of potash on calcareous potassium-deficient soils in Berkshire, the drilled material at 0·5 cwt./acre giving rather better results than double this dressing broadcast on the seedbed (Figure 2). In more recent work [16, 17] it was also found that, on mineral soils deficient in potassium, combine-drilling a dressing of potash fertilizer gave consistently higher yields of barley than twice as much broadcast potash. With nitrogen fertilizers, however, combine-drilling and broadcasting on the seedbed were equally good.

It may therefore be concluded that where phosphorus or potassium fertilizers are justified for cereals they should be applied by combined seed and fertilizer drill. The cash savings made by combine-drilling as compared with broadcasting are not great: the cost of fertilizer needed to produce a given yield may be reduced by perhaps £1 an acre at current prices; in the experiments reported by Crowther [11] combine-drilling of 3 cwt./acre of superphosphate produced about 2 cwt. more grain than broadcasting—a gain worth about 50s. an acre today. On many of the better soils drilling a little PK fertilizer with cereal seed may be regarded as an insurance against unsuspected soil deficiencies.

ROW CROPS

Several crops grown in wide rows (12 in. or more apart) give higher yields from placement; but the method has no advantage for sugar beet, mangolds or kale, and it is inferior to broadcasting for carrots.

Potatoes

The traditional English way of planting potatoes was to ridge the field, plant seed by hand in the furrows, and then to split the ridges to cover the seed. In early experiments [2] comparing different methods of applying National Compound Fertilizer No. 1 (7–7–10·5)* to potatoes planted in this manner no differences were found between yields given by fertilizer dressings placed at the side of the seed by a special machine and by the same quantities broadcast over the furrows immediately before planting. Broadcasting on the flat before drawing out the furrows was less effective, 15 cwt./acre of fertilizer applied in this way giving the same yields as only 10 cwt./acre broadcast over the furrows just before planting.

These experiments showed that fertilizer efficiency may often be improved merely by using broadcasting equipment in a different way. When fertilizer is broadcast over furrows just before planting potatoes, splitting the ridges after planting concentrates the dressing over and around the seed and nothing is to be gained from special placement methods.

Since 1947, when these experiments were concluded, methods of planting potatoes have changed rapidly. Probably half of the acreage under potatoes was planted by machine in 1952, and it is believed that the proportion is increasing. When machines are used there is no opportunity to concentrate broadcast fertilizer near the seed, for they normally work on flat land, planting and forming the ridges in one operation.

This problem has recently been investigated [8] using a potato planter modified by adding equipment to place bands of fertilizer either with or beside the seed, and comparing different methods of broadcasting and placing a 7–7–10·5 fertilizer. Fertilizer broadcast early and cultivated deeply into the soil gave much the same results as broadcasting on the seedbed just before planting, but placement in one band to the side of the seed, and slightly below its level, gave higher yields (Figure 1). On the average of all experiments, 15 cwt./acre of broadcast fertilizer gave about the same yields as 10 cwt./acre of placed fertilizer.

Yields and cash returns from these trials, set out in Table I, show an extra profit from placing as compared with broadcasting of about £12 an acre for the light (7·5 cwt./acre) dressing and £9 an acre for the heavy (15 cwt./acre) dressing; similar returns are likely to be obtained on ordinary soils in England, so that the extra cost of having a placement attachment on a potato planter may be written off after planting only a few acres.

Although many commercial mechanical planters are adapted to place fertilizer in contact with the seed, the experiments showed that under certain conditions this practice may be harmful. There was little difference between the yields given by

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* Fertilizer analyses are given here in an abbreviated form, thus 7-7-10·5 implies a fertilizer containing 7% N, 7% P_2O_5, 10·5% K_2O.

TABLE I

AVERAGE YIELDS AND NET CASH RETURNS IN 33 EXPERIMENTS IN 1951 AND 1952 COMPARING BROADCAST AND PLACED FERTILIZER FOR MACHINE-PLANTED POTATOES

	Yield (tons/acre)	Profit* from fertilizer/acre
Without fertilizer	6·4	—
With broadcast fertilizer		
at 7·5 cwt./acre	8·7	£20
at 15 cwt./acre	10·3	£31
With placed fertilizer		
at 7·5 cwt./acre	9·7	£32
at 15 cwt./acre	11·1	£40

* Assuming current prices for crops and fertilizers.

contact and side-band placement when medium fertilizer rates were used, but heavy dressings in contact reduced yields at several centres. Observations in the early part of the growing season showed that contact placement generally delayed emergence by 7–10 days, but on light land emergence was sometimes delayed by as much as three weeks, plant establishment was reduced, and yields were lowered.

Peas and Beans

Farmers using combine-drills for crops like peas have often found that compound fertilizers may impair germination, and experiments show that the extent of damage depends on the nature and amount of fertilizer, texture and moistness of the soil at sowing, and on weather conditions. Even 2 or 3 cwt./acre of phosphate-potash fertilizer can be harmful if dry weather follows sowing. Heavy dressings of sulphate of ammonia and muriate of potash damage germination when placed with or directly below the seed, but superphosphate can be used safely.

In field experiments using a special drill [3] placing such PK fertilizers as 0-10-20 and 0-14-14 in contact with the seed or directly below it was liable to reduce plant establishment seriously. A single side-band 1 in. away from the seed and about 3 in. below the soil surface was found to be too close to the seed for safety, whereas 3 in. was too far away. In subsequent trials on peas and other row crops a distance of 2 in. to the side of the seed was found to be safe.

Small dressings of broadcast phosphate and potash fertilizers can be justified for beans, but for peas grown on most soils the only fertilizer that can be recommended for broadcasting is muriate of potash at about 1 cwt./acre [12]. Trials on peas and beans were begun in 1947 to see if extra yields could be obtained by placing PK fertilizers (0-13-13 or 0-10-20) 2 in. to the side of the seed and 3 in. below the soil surface. Results of this work have been published [3, 6]. The average yields obtained, stated in Table II, show that for the four kinds of crop used placing 3 cwt./acre gave higher yields than broadcasting twice as much (Figure 6). Broadcasting fertilizer for threshed peas and both kinds of beans lost money at current prices, though it gave a small cash return on green peas. Placement, however, was profitable on all

TABLE II

AVERAGE YIELDS (CWT./ACRE) IN EXPERIMENTS COMPARING BROADCAST AND PLACED FERTILIZER FOR PEAS AND BEANS

	Threshed peas	Green peas (peas + pods)	Winter beans	Spring beans
No. of experiments	17	7	9	10
Without fertilizer	13·7	72	16·8	16·3
With broadcast fertilizer:				
at 3 cwt./acre	14·1	74	18·2	16·9
at 6 cwt./acre	14·8	76	18·4	16·9
With placed fertilizer:				
at 3 cwt./acre	15·9	82	18·9	18·1
at 6 cwt./acre	16·4	87	19·7	18·3

crops, and for green peas it yielded the very high return on the dressing of about £20 an acre.

Experiments have been extended to the main pea-growing areas by the National Agricultural Advisory Service in collaboration with Rothamsted Experimental Station, and the results have recently been described for threshed peas [5] and for green peas [1]. In both series the increase in yield from placing as compared with broadcasting 3 cwt./acre of PK fertilizer was about 2 cwt./acre of dried peas and about 8 cwt./acre of green peas. Such gains more than pay for the fertilizer and over a few seasons will justify the purchase of a special drill.

These results show how misleading it may be to carry out trials solely with broadcast fertilizers: absence of response may be due to fertilizers having been applied in the wrong place.

Horticultural Crops

Few British experiments have attempted to define the kinds and amounts of broadcast fertilizer that are most profitable for horticultural crops. In recent trials [10] a 7-7-10·5 fertilizer was applied by means of a specially built one-row drill in one band 2 in. to the side of the seed and 1 in. deeper, and the dressings were compared with the same amounts of broadcast fertilizer worked into the seed-bed. Placement was found to be superior to broadcasting for all crops except beetroot (Table III). Most of the vegetables gave higher yields from 2·5 cwt./acre placed beside the seed than from 5 cwt./acre broadcast, and placing the heavier dressing increased yields still further (Figure 5).

An important advantage of placement over broadcasting, observed in these trials for lettuce, cabbage, runner beans and broad beans, is that the crops can be ready for market earlier and so command high prices and be very profitable to growers.

This work was carried out on ordinary arable land, vegetables being taken as one crop in the rotation, and it indicates that where large acreages of horticultural crops are grown on farmland the use of a placement drill may be very profitable. On old-established market garden soils which have been heavily dressed with organic manures, fertilizer dressings are not likely to give sizeable increases in yields.

In other trials, placing nitrogenous top-dressings close to established crops of cabbage and brussels sprouts did not give better yields than those obtained by the usual practice of broadcasting.

Swedes and Turnips

In experiments in England on swedes grown on the flat, placing fertilizer beside the seed gave higher yields than broadcasting equivalent dressings [3].

In Scotland, where roots are normally grown on ridges, it was found [15] that applications of a complete fertilizer to swedes by the two methods generally gave much the same results, for broadcast dressings are concentrated when the ridges are set up, so that partial placement is achieved. Trials with the separate constituents of a compound fertilizer showed that superphosphate gave better results when placed directly beneath the seed than when broadcast, though the benefits from placement were less when superphosphate was applied

TABLE III

AVERAGE YIELDS (CWT./ACRE) IN EXPERIMENTS IN 1952–54, COMPARING BROADCAST AND PLACED FERTILIZER FOR HORTICULTURAL CROPS

	No. of experiments	Unmanured yield	Response to broadcast fertilizer	Gain from placing *over* broadcasting
Cabbage	4	97	47	23
Lettuce	6	124	18	23
Beetroot	3	58	5	4
Onions	2	209	24	28
Maize	2	103	7	14
Broad beans	5	64	2	12
French beans	3	72	− 5	5
Runner beans	5	96	7	7
Spinach	1	82	9	31

in a band 2 in. to the side of the seed. Both sulphate of ammonia and muriate of potash reduced germination when placed directly under the seed, the damage being least when wet weather followed sowing; side-band placement of these soluble fertilizers did not affect germination, but yields were similar to those from broadcast dressings.

Sugar Beet and Mangolds

In 30 experiments with mixed fertilizers applied to sugar beet [3, 4] placement beside the seed gave quicker growth during spring and early summer than broadcasting, yet the two methods gave almost identical yields of sugar and tops. Mangolds were found in other trials to behave in the same way as beet.

Kale and Carrots

Placing a PK fertilizer beside the seed gave better early growth of kale than broadcasting (Figure 3), but, as with beet, there was little gain from the method when the crop was harvested six months later [6]. In a few trials on carrots broadcast fertilizer gave higher yields than placed dressings.

HERBAGE CROPS

When herbage crops are grown in an arable rotation, fertilizers may be applied at different stages in the cultivations that precede sowing. Satisfactory establishment requires a high concentration of phosphate near the seed, particularly where this element is deficient, and it has been shown [19] that phosphate fertilizers drilled in contact with grass and clover seeds promoted better establishment of temporary grassland than the same quantity of phosphate broadcast before sowing.

Lucerne

In two field experiments with PK fertilizer on lucerne [7], placement 2 in. to the side of the seed did not improve early growth, and broadcast and placed dressings applied at the same rate gave similar yields over two harvest years. Comparisons were also made between applying the whole dressing of fertilizer in the seeding year and applying half at sowing and the remainder in the following year. There was no advantage from splitting the dressing.

In another experiment on lucerne a "starter dose" of 2 cwt./acre of granular superphosphate was drilled 2 in. below the seed and tested with and without broadcast superphosphate and muriate of potash. "Starter" superphosphate gave very much better growth of lucerne throughout spring and early summer than any of the dressings of broadcast fertilizer (Figure 4). The striking result of the experiment was that 2 cwt./acre of superphosphate placed under the seed gave increases in yield of the first two cuts several times greater than the increases given by 5 cwt./acre of broadcast superphosphate. When the "starter dose" was used, none of the dressings of broadcast fertilizer had any worth-while effect.

Lucerne is a deep-rooting crop, and where side-band placement was tested, the plants 8 weeks after sowing had long straight tap roots with very few laterals, but no roots near the fertilizer band. With such a root system young plants are unable to use fertilizer placed beside the seed, and better results are obtained by placing superphosphate directly beneath the seed and therefore in the track of the developing tap root. Fertilizers containing soluble salts are likely to damage germination when placed directly under the seed, hence "starter doses" must be restricted to light dressings of superphosphate. It is not necessary to use specially built drills to carry out this practice, since a combined seed and fertilizer grain drill can be adapted to sow lucerne and to place a band of fertilizer directly under the seed.

Established Herbage Crops

Fertilizers for established herbage crops are usually broadcast over the surface; but dressings of phosphate and potash applied in this way may remain on the top of the soil and be of little value, so the possibility of applying them below the sward was examined [7]. In experiments on sainfoin, lucerne and permanent grass, PK fertilizer drilled in bands 3 in. below the soil surface gave lower yields of hay than surface dressings of the same fertilizer. The advantages of an equal supply of nutrients to all the plants in an established sward appear to outweigh any disadvantages of confining the dressings to the surface.

"PLACEMENT" EFFECTS BY BROADCASTING

It is often possible to concentrate fertilizers in some desired position in the soil by broadcasting them at different stages in the cultivation of arable land. An example has already been given where the benefits of placement were obtained for potatoes merely by broadcasting fertilizer over the furrows in which the crop was to be planted by hand. Such methods, which are possible without using special equipment, often have considerable advantages over the common practice of broadcasting on the surface of a prepared seedbed.

In a number of experiments on peas and beans [6] dressings of fertilizer broadcast early and either ploughed or cultivated deeply (4–6 in.) into the seedbed were compared with late dressings broadcast on the seedbed and harrowed in shallowly (1–2 in.). In very dry periods fertilizer confined to the surface soil was useless, but both placed fertilizer and broadcast fertilizer incorporated deeply improved yields; in wet conditions early dressings ploughed in gave the same yields as late dressings harrowed into the seedbed. It is therefore recommended that where special placement drills are not available, farmers should broadcast fertilizer for beans and peas before cultivating to prepare the seedbed or, if possible, plough the dressings in. In some seasons early and late broadcasting may be equally effective; in other seasons early applications may give higher yields, and deep dressings are unlikely to be less efficient than seedbed dressings. In contrast, for sugar beet Cooke [4] showed that broadcasting dressings early and working them in deeply had no advantage over spreading fertilizers on the seedbed.

Russell [18] concluded that, for sugar beet at Rothamsted, deep or even shallow ploughing in of phosphorus and potassium fertilizers was more beneficial than their application to the seedbed. Further, the response to deep ploughing was greater when fertilizers were ploughed in than when they were put in the seedbed. There is not enough evidence, however, to justify a general recommendation that farmers should plough in phosphates and potash, though there are indications that this might be an advantage for deep-rooting crops.

The effects of "split" applications have been tested on peas, beans, sugar beet, kale and carrots. When half of the fertilizer was broadcast and half placed beside the seed, the gains in yield obtained by splitting, as compared with placing the whole dressing, did not cover the cost of the extra operation.

THE PRACTICAL VALUE OF PLACEMENT

Placing "Starter" Fertilizers

Rapid growth is promoted by "starter" phosphorus placed near the seed, and this effect, which has been demonstrated on a variety of crops, may persist until harvest or become less marked as the season advances. It is not certain whether high concentrations of placed nitrogen and potassium also promote rapid early growth.

"Starter" fertilizers must be placed where the roots can absorb them immediately after germination. For cereals a light dressing of superphosphate may be drilled in contact with the seed. For tap-rooted crops superphosphate should be placed directly below the seed.

Placing Complete Fertilizers

The advantage of placing all the fertilizer for such crops as potatoes is that the nutrients, being in moist areas of the rooting zone, are made available throughout the growing season. Similarly, placing NPK fertilizers close to the seeds of some quickly growing horticultural crops concentrates the nutrients in a zone where the roots are continuously active; this is a pronounced benefit, for such crops are ready to market before their root systems are large enough to use broadcast fertilizer efficiently.

For other crops potash and phosphate fertilizers seem to promote greater growth when placed than when broadcast at the same rate, even where the broadcast dressings are fully accessible to the roots. On soils of poor to average fertility, placing these fertilizers does not make peas and beans grow rapidly in the early stages—though visual benefits are often seen when the crops are well established—but yields are higher than those obtained when much larger quantities are broadcast and worked into the surface soil. Such gains are not due to "starter" effects: it is possible that some crops can take up enough nutrients for full growth only from relatively high concentrations of potash or phosphate, and placement provides locally concentrations that cannot be achieved economically by broadcasting, and which are found normally only in rich soils.

Factors affecting the Value of Placement

In areas where no investigations have been carried out the value of placement practices must be decided by empirical field work. The concepts set out below may help to explain the success or failure of placement methods for specific crops and for different cultural conditions, and they may be of use in planning field investigations.

(i) Plants can utilize fertilizers only from zones of the soil where their roots are active; a function of placement is to concentrate fertilizer in the root zone.

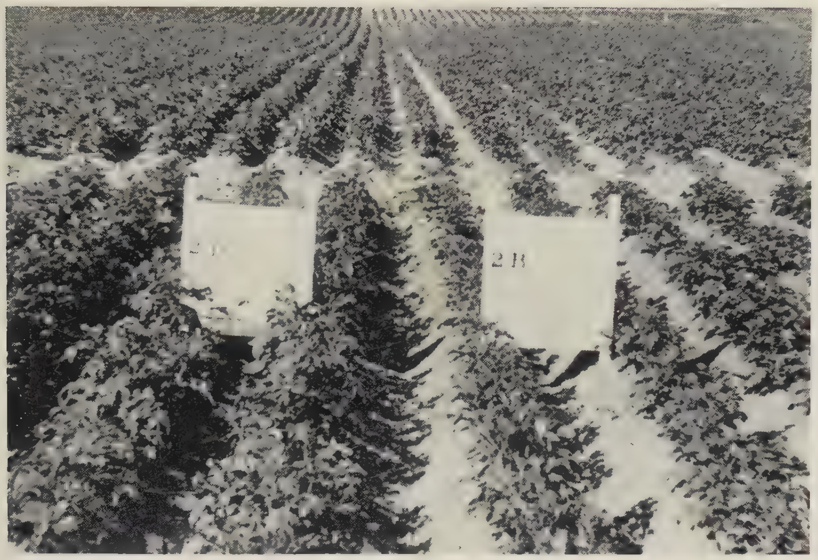
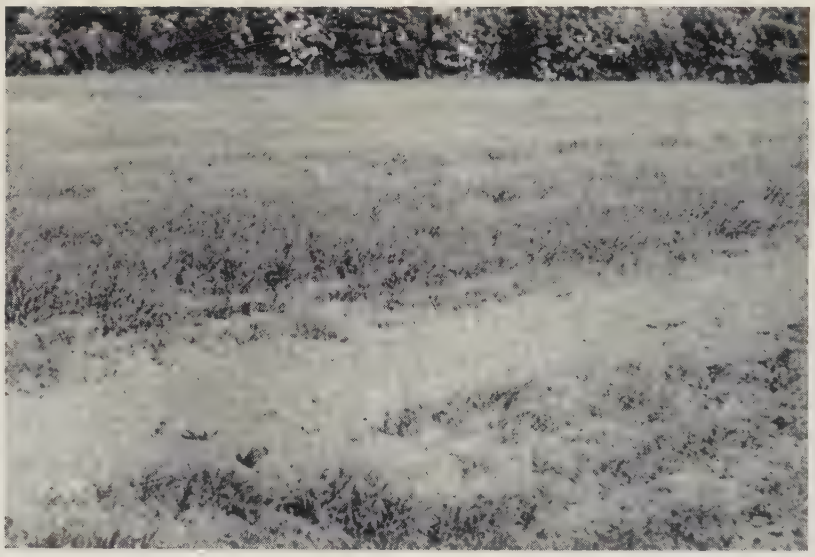


FIG. 1. Potatoes. Placing fertilizer to the side of the seed (left-hand plot, 2D) gives better results than broadcasting before planting (right-hand plot, 2B). Both these plots received 15 cwt./acre of 7-7-10·5 fertilizer.

FIG. 2. Cereals. Drilling potassium fertilizer with the seed was essential for the crop shown in the background. No potassium fertilizer was applied at sowing time to the foreground crop.



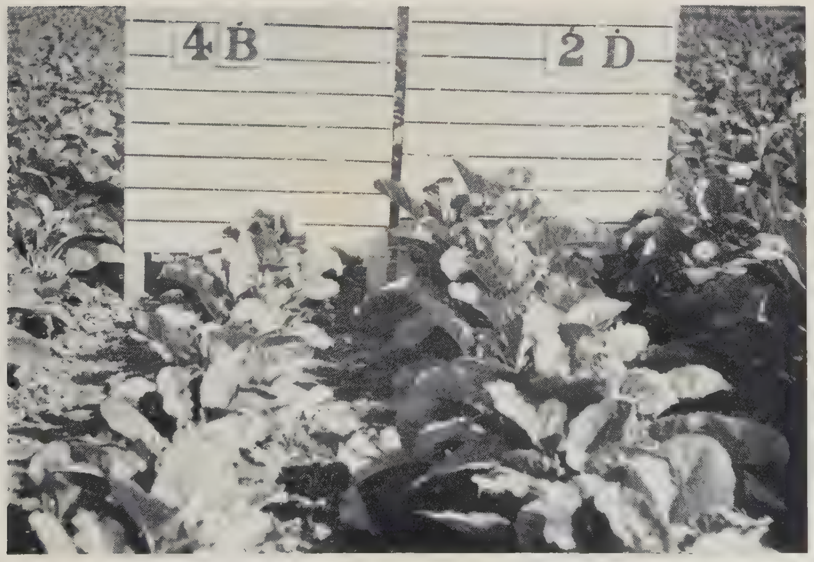


FIG. 3. Kale. Rapid early growth is promoted by placed fertilizer. Plot 2D (right) received 5 cwt./acre of PK fertilizer placed near the seed, whereas twice this amount was broadcast on plot 4B (left).

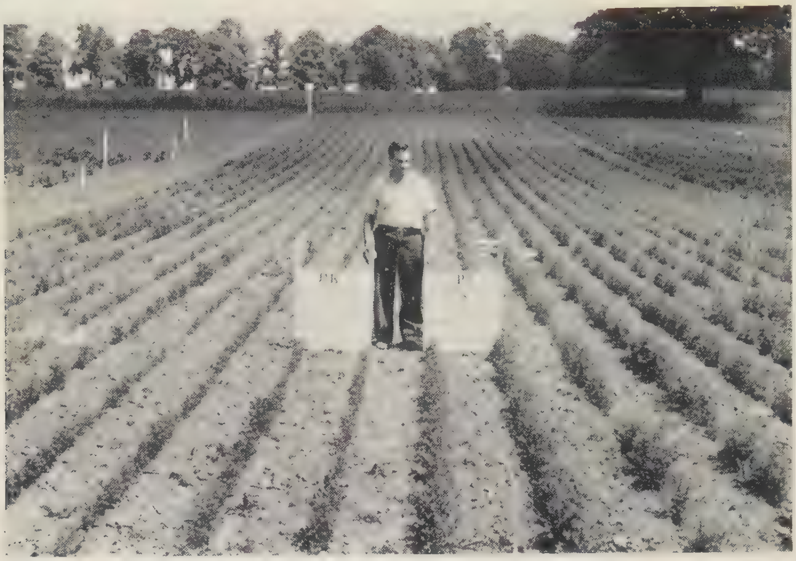
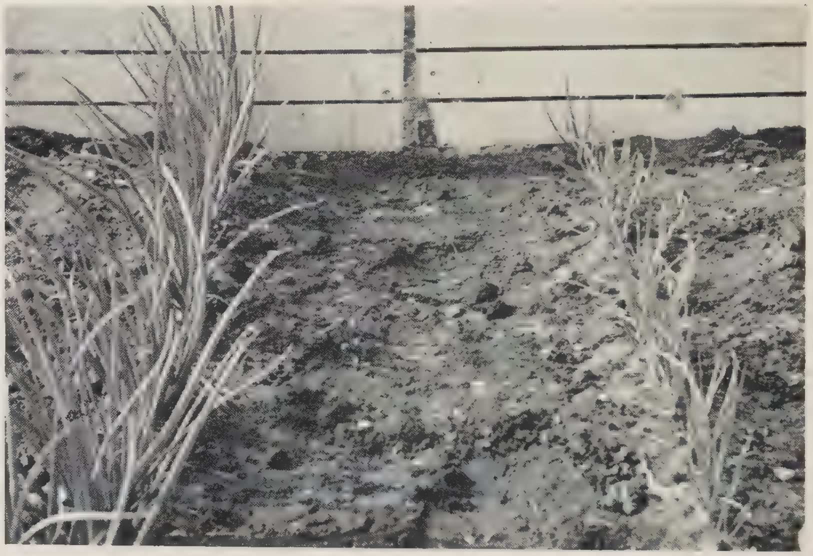


FIG. 4. Lucerne. A "starter dose" of 2 cwt./acre of granular superphosphate drilled below the seed greatly improves growth. This is well shown here (right-hand plot, PK/S) on land that has received a PK fertilizer broadcast.

FIG. 5. Onions. Higher yields are obtained by placing than by broadcasting fertilizer. The row on the left received 2·5 cwt./acre of 7-7-10·5 fertilizer beside the seed, and that on the right 5 cwt./acre of the same fertilizer broadcast.



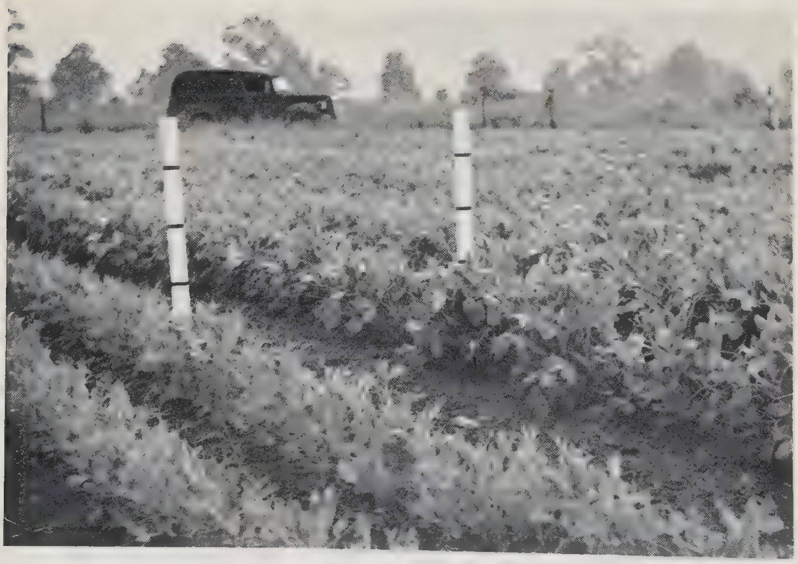


FIG. 6. Peas. Placement of a PK fertilizer 2 in. to the side of the seed can be highly profitable. This photograph shows the effect (right) of placing 3 cwt./acre of a PK fertilizer and (left) of broadcasting twice as much.

(ii) Roots cannot absorb nutrients from dry soil; placement may be the only efficient method of getting nutrients below the surface and into moist soil.

(iii) Crops with a short growing season require a good supply of nutrients throughout their life; any deficiency that checks growth reduces yields. Long-season crops take up nutrients over a long period. Often the highest rate of uptake occurs in the later stages of growth; a rapid start is less important, and crops may "grow away" from an early check.

(iv) Crops with poor root systems are less well equipped than those with good root systems to take up fertilizers distributed through the soil. Crops with tap roots use nutrients incorporated deeply in the soil; those with well-developed lateral roots use nutrients in the soil between the rows.

(v) Inorganic nitrogen fertilizers are mobile in soil moisture, and surface dressings are washed into the root zone by rain. Potassium fertilizers are fairly mobile in light soils and move to the roots; on heavy soils potassium combines with colloids and may not move very far, therefore it should be placed near the roots. In practically all soils soluble phosphorus fertilizers combine with clay colloids or calcium compounds and cannot move to the roots, hence phosphate fertilizers must be placed in a zone of the soil where roots will develop soon after germination; the same is true for potassium fertilizers in heavy soils.

(vi) In developing placement methods for new crops, root systems should be studied. If "starter dose" effects are required, water-soluble phosphate must be placed with or directly under the seed, particularly if a vigorous tap root is produced. If many lateral roots are formed soon after germination, side-placement may be adequate, and it is also likely to be suitable for large-seeded legumes, which do not require fertilizer immediately after germination.

Placement is a subsidiary aspect of manuring. Before it can be considered, a general manurial policy must be decided by using average crop requirements determined by field experiments, the results of soil analysis, and the previous history of individual fields. When the quantities of fertilizer needed have been defined, the best methods of applying them must be chosen for each crop. Correct placement is one of these, and, whether achieved by special methods or a particular way of broadcasting, it is often necessary if the best returns are to be obtained from fertilizer dressings.

In general, the benefits from placement are likely to be greatest on soils that are deficient in available plant nutrients, and the technique often allows crop production to be brought up to a high level in a short time. On soils that have been adequately manured for many years the returns are likely to be less. On the richer soils, however, placement is a suitable way of applying the small dressings needed as insurance against unsuspected soil deficiencies, attacks by pests and diseases, or unfavourable growing conditions.

REFERENCES

[1] Bullen, E. R., Dadd, C. V. and Cooke, G. W. (1954). *Agriculture, Lond.*, **61**, 19–22.

[2] Cooke, G. W. (1949*a*). *J. agric. Sci.*, **39**, 96–103.

[3] Cooke, G. W. (1949*b*). *J. agric. Sci.*, **39**, 359–73.

[4] Cooke, G. W. (1951). *J. agric. Sci.*, **41**, 174–8.

[5] Cooke, G. W. and Dadd, C. V. (1953). *Agriculture, Lond.*, **60**, 34–8.

[6] Cooke, G. W. and Widdowson, F. V. (1953*a*). *J. agric. Sci.*, **43**, 348–57.

[7] Cooke, G. W. and Widdowson, F. V. (1953*b*). *J. agric. Sci.*, **43**, 358–64.

[8] Cooke, G. W., Jackson, M. V. and Widdowson, F. V. (1954). *J. agric. Sci.*, **44**, 327–39.

[9] Cooke, G. W. and Widdowson, F. V. (1955). *Field Crop Abstracts*, **8**, 233–7.

[10] Cooke, G. W., Jackson, M. V., Widdowson, F. V. and (in part) Goodway, N. D. (1956). *J. agric. Sci.*, **47**, 249–56.

[11] Crowther, E. M. (1945). *Agriculture, Lond.*, **52**, 170–3.

[12] Crowther, E. M., Reynolds, J. D. and Shorrock, R. W. (1952). *Agriculture, Lond.*, **58**, 584–8.

[13] Lawes, J. B. (1847). *J. Roy. Agric. Soc. E.*, **8**, 494.

[14] Miles, R. O. (1947). *Bull. Jealott's Hill Res. Sta.*, No. 4, 31.

[15] Reith, J. W. S. (1954). *J. Sci. Fd Agric.*, **5**, 421–8.

[16] Rothamsted Experimental Station (1954). *Rep. Rothamst. exp. Sta.*, 1954, 41–2.

[17] Rothamsted Experimental Station (1955). *Rep. Rothamst. exp. Sta.*, 1955. (In the press.)

[18] Russell, E. W. (1949). *Rep. Rothamst. exp. Sta.*, 1949, 130–47.

[19] Stewart, A. B. and Reith, J. W. S. (1945). *Scot. J. Agric.*, **25**, 167–71.

IMPROVEMENTS IN THE STRUCTURAL STATE OF SOILS UNDER LEYS

A. J. Low

That soil tilth and crop yields become poorer after ploughing out from grassland has long been observed, and a return to grass is recognized to be the most practical way of restoring lost fertility. How long this might take, however, is uncertain. The investigations described here show that complete restoration would require many years under conditions in Britain, though even a short ley can improve structure and plant growth.

It has long been recognized that the physical condition of a soil, from the points of view of cultivation and crop growth, is at its best in the year or so following the ploughing out of an old pasture, and that with arable farming this optimal condition is not maintained. In medieval Britain, to maintain soil fertility two successive crops of cereals were usually followed by 1 year weed fallow, which was grazed, the plants that grew during the fallow being self-sown. The deliberate sowing of grass and clover seeds for the resting period did not begin until the seventeenth century. During the eighteenth and nineteenth centuries the grass-clover break varied from 1 to 3 years, and Elliot (1898) suggested "four to six years good turf on old arable land would restore it to a condition comparable with old pastures."

During the twentieth century ploughing of old grassland in Britain was rare until the outbreak of war in 1939, when it became commonplace. In many cases the contrast between the physical condition of this soil and that of corresponding old arable land was most marked, raising the question of how long it takes to restore old arable land to the physical condition of old grassland. As the answer might vary with soil type, seeds mixtures, climatic conditions and other factors, it was decided to make observations on farms in different parts of England and Wales, comparing on each an old arable soil about to be sown to a ley with, nearby, old pasture of the same soil type.

This paper describes some of the results obtained on twenty-two farms from field observations over a period of years and measurements of the stability of air-dry soil aggregates to wetting.

METHODS

How was one to know when old arable land under grass was restored to the condition of old grassland? There appeared to be at least two approaches to this problem: either to plough the ley and compare its physical state and cropping capacity with old grassland ploughed at the same time, or to leave the fields unploughed and attempt to compare the physical state of the soils both *in situ* and on samples in the laboratory. The first method would give a more definite answer, but the complicated field trials required would make it impossible to cover a wide range of soil types; hence the second method was chosen.

Field studies were generally descriptive. Main points considered were size and shape of the aggregates, size and shape of the pores and channels, and properties resulting from the types of aggregates and their distribution, such as compactness of the soil, stickiness, and ease of breakdown of aggregates on crushing. Observations on plant and animal life were also made, notably on the activities of worms, and on the distribution of roots together with indications of impeded drainage.

Field and laboratory methods have been described previously [14]. The sampling areas were 20 × 20 yards, and they were visited each spring and autumn, in some cases for 9 years. For studies of the water stability of soil aggregates samples were air-dried, crushed, and passed through a $\frac{1}{2}$-in. sieve.

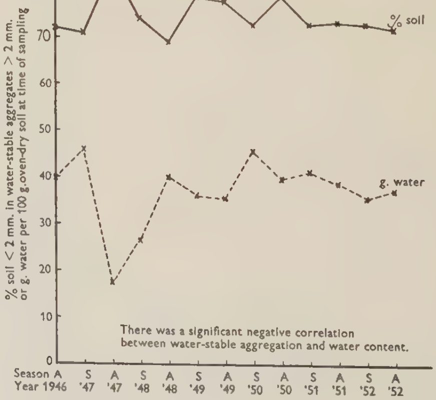


FIG. 1. Relationship between water-stable aggregation and water content of soil at sampling (spring and autumn).

Examination of a clay loam in permanent pasture for at least 110 years (J.H. 18) showed that the percentage of water-stable aggregates exceeding 2 mm. was not constant over a period of 6½ years, and that the greater the water content at sampling time the lower was the water stability of the air-dry soil (Figure 1). A similar relationship was shown for a ley.

That variation in water stability was not due merely to field sampling errors is indicated by seasonal changes which occurred in four adjacent fields that had been under grass for varying periods of time (Figure 2).

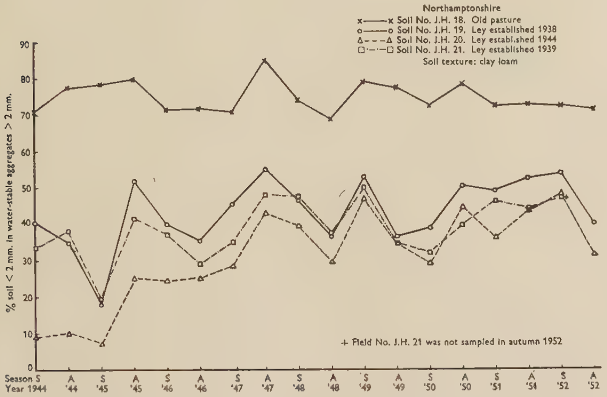


FIG. 2. Seasonal changes in water-stable aggregation in three leys and an old pasture.

Similar results were obtained in many fields sampled in different parts of England during a period of 9 years. This suggests that the drier conditions are for ploughing and cultivation the more stable the structure (or tilth) is likely to be. Farmers usually claim that the best yields of cereals have followed ploughing under dry conditions in the autumn.

In addition to the variations in aggregate stability between spring and autumn, variations over 6-week periods (Figure 3) and from day to day have been found. In each case the percentage of water-stable aggregates appeared to be related to the water content at the time of sampling. Seasonal and other variations in aggregate stability have been observed by other workers [2, 5–7, 10, 19, 24].

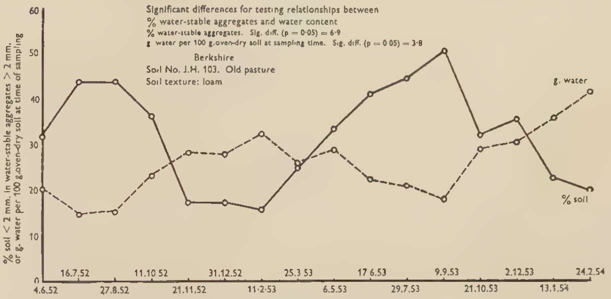


FIG. 3. Water-stable aggregation and water content of soil at sampling (six-weekly intervals).

The dynamic nature of soil structure makes comparison over a period of time at a single site difficult. Owing to seasonal variations, short-term studies of the changes in aggregate stability of leys may be misleading. Apart from seasonal variations, aggregate stability of a ley does not always increase steadily with time (Figure 2), but downward trends are usually accompanied by corresponding changes in adjacent old pasture. In order to find the time required for arable soils to reach the old-pasture condition, changes in aggregate stability of a ley *relative* to corresponding old pasture were measured. Two methods of setting out the results were used: (1) plotting percentage of water-stable aggregates against time (Figure 2), and (2) calculating

$$\frac{\text{per cent water-stable aggregates} > 2\text{ mm. in a ley}}{\text{per cent water-stable aggregates} > 2\text{ mm. in old grassland}} \times 100$$

which is referred to as the index of aggregation, or I.A. While the former shows long-term trends towards the condition of old pasture reasonably clearly, the I.A. is better over short periods. The I.A. will be 100 when the per cent of water-stable aggregates of the ley is equal to the corresponding old-pasture soil.

SYSTEMATIC STUDIES

No systematic study of the changes in the structural state of an arable soil after establishing a ley on it appears to have been made in Britain or elsewhere other than by Low (1950), who described the effects of leys of varying length on a clay loam at one farm in eastern England. An account follows of the soils, field observations of structure, laboratory measurements of water stability of aggregates, and management of leys at four of the twenty-two farms studied. Mean annual indices of aggregation are shown in Table I.

Farm No. 1—Cumberland

This field had been cultivated for many years before it was undersown in oats in 1943 with ryegrass and white clover. The soil was first sampled in spring 1944, when a good ley had developed. One hay crop was taken in that year, after which the field was grazed with either cattle or sheep, but never overgrazed. Root development was very

TABLE I

INDICES OF AGGREGATION AND SOIL ANALYSES AT FOUR FARMS

Year* of ley	Management	I.A.	Mechanical analysis (%)†		
				Old pasture	Ley
Farm No. 1—Cumberland. Coarse, sandy soil					
1	Grazed	—	Coarse sand	53	53
2	Hay	77	Fine sand	20	19
3	Grazed	90	Silt	14	16
4	Grazed	88	Clay	13	12
Farm No. 2—Lancashire. Sandy loam					
1	Grazed well	31	Coarse sand	22	20
2	Grazed well	45	Fine sand	32	27
3	Grazed well	52	Silt	31	31
4	Hay	63	Clay	15	22
Farm No. 3—Shropshire. Loam					
1	Grazed hard	1	Coarse sand	33	30
2	Grazed hard	3	Fine sand	15	17
3	Grazed hard	7	Silt	28	30
4	Grazed hard	18	Clay	24	23
Farm No. 4—Northamptonshire. Clay loam					
1	Barley undersown	13	Coarse sand	11	11
			Fine sand	23	20
2	Grazed	20	Silt	37	32
3	Hay	35	Clay	29	37
4	Hay twice	46			
5	Grazed	48			
6	Hay	52	Note. Data for 1944 ley only. The old pasture contained 11% organic matter.		
7	Grazed	48			
8	Grazed	54			
9	Hay	55			

* Year of sowing (if in spring) is first year of ley.

† By Bouyoucos's hydrometer method: coarse sand = 2,000–200 μ, fine sand = 200–50 μ, silt = 50–2 μ, clay = < 2 μ.

good down to 6 in. at least. Worm and mole activity were marked.

From field observations little difference between the ley and the adjacent old-pasture soil could be detected in 1946 except that the latter was more mellow. The soil was not sampled before the ley was established, but an adjacent old-arable field of the same soil type and similar history had an I.A. of 49 in 1946, while that of the ley was 88. There seems little doubt that the initial I.A. of the ley was similar to that of the old-arable soil, the I.A. of which remained constant over the 4 years. The overall extent of aggregation in both ley and old pasture was small, most of the soil being non-aggregated sand. The aggregates, although resistant to slaking and sieving, were mechanically weak when dry. The water stability appeared to be largely due to binding by roots.

Farm No. 2—Lancashire

This field had been arable for many years before it was direct reseeded in spring 1944 with a ryegrass-clover mixture. It was first sampled in autumn 1944, when there was an excellent close-knit sward. The field was well managed by adequate manuring and grazing, avoiding poaching and winter grazing. Root development (0–6 in.) was markedly seasonal, being good in spring but poor in late autumn, when many roots were rust coated. Worms increased over the four years to reach 500,000–1,000,000 per acre (0–6 in.). At the last sampling when the field was closed for hay there was a marked development of crumb-like aggregates, 3–4 mm. in diameter.

The I.A., which was initially 29, increased after reseeding to the final value in spring 1948 of 64. This was attributed to good management. Structure as observed in the field improved considerably and was becoming similar to the old pasture by spring 1948. Although the drainage was imperfect, good management ensured that the soil never became really compact.

Farm No. 3—Shropshire

This was an old arable field which, despite manuring, was yielding very poor crops. It was direct reseeded with a ryegrass-clover mixture in spring 1944 and received adequate supplies of fertilizers, yet the sward did not grow well until its fourth year. It was always grazed hard, usually by sheep. Root development was quite good during the first year but it was small in subsequent years, especially below 3 in. Development of crumb-like aggregates was slight, and the soil remained very compact until the spring of 1947, when it became both much more porous and more mellow to dig. This coincided with a better sward and a marked increase in worm population to 500,000 per acre (0–6 in.).

The I.A. rose from the very low initial of 1 in spring 1944 to 19 in the fifth year of the ley.

Physical condition of the ley after 4 years was much inferior to that of the corresponding old pasture.

Farm No. 4—Northamptonshire

Structural changes here were studied on three leys on very old arable land. In spring 1944 one field (J.H. 20) was in spring barley and undersown with ryegrass and clover. The other two were leys established similarly in 1938 and 1939. The leys were adjacent to a pasture at least 110 years old taken as standard.

The ley established in 1944 was well grazed with beef cattle and remained clovery (40–50%) until the latter part of 1951, when the proportion of clover fell, becoming less than 5% in 1952. Root development was fairly good in the first 4 years, but there was little increase afterwards. The rate of increase of I.A. fell off after 4 years. Worms increased from few at first to about 600,000 per acre (0–6 in.) by 1952. Physical changes in the soil were clearly seen in the field. In the first 2 years the soil was very sticky when wet, but after 1946 this became hardly noticeable; this change seemed to be correlated with increased aggregation of the soil particles less than 50 µ (Low, 1954). By spring 1946 the soil, which had been very compact, tended to break into hard angular aggregates 2–3 cm. side, and thereafter these became smaller and less angular until by autumn 1952 they were about 5 mm. in diameter and somewhat rounded, but even then they were much more closely packed than those in the old pasture. In 1947 physical differences between these leys were small.

The I.A. was 12 at sowing and 66 in the last year of sampling. Although the structural state improved considerably, it remained much inferior to the old pasture (Figure 4).

The ley established in 1938 (J.H. 19) was grazed steadily for many months each year with sheep and beef cattle and hayed three times in the first 6 years. It never poached. In 1944, although the ley was in its seventh year, its structural state was much inferior to that of the old pasture: it was much paler in colour; the aggregates were much more angular and closely packed; there were fewer roots. Between 1944 and 1952 the structural state slowly changed, the aggregates becoming rounder, smaller, more porous, and less closely packed; yet it remained much inferior to the old pasture. Root development increased. Worm numbers rose from 500,000 to 2,000,000 per acre (0–6in.). The I.A. was 75 at the last spring sampling.

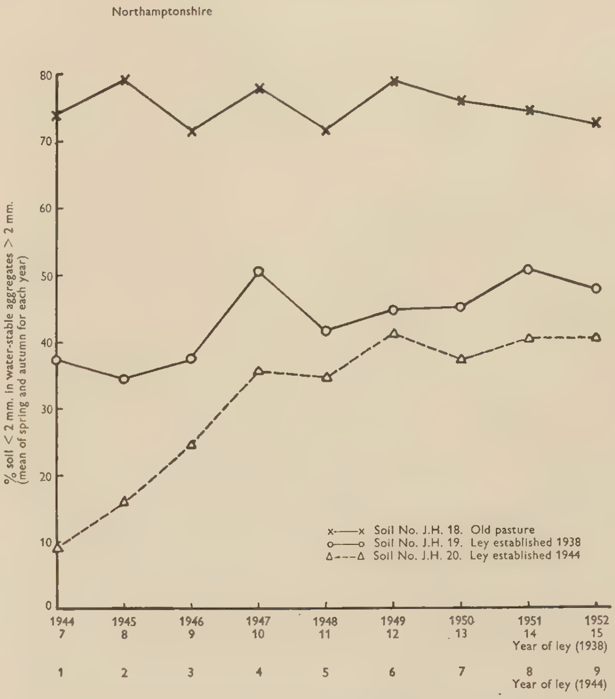


FIG. 4. Annual changes in water-stable aggregation.

Similar comments apply to the 1939 ley except that field observation usually indicated a poorer structure; it is noteworthy that this field was the only one of the three to poach occasionally. Structural differences between the 1938 and 1939 leys observed in the field agreed with laboratory determinations of water stability of aggregates (Figure 2). This was so to a remarkable extent on all the farms.

In Figure 4 the annual water-stable aggregation is plotted against time for the 1938 and 1944 leys. For the 1938 ley increase was slow from the seventh to the fifteenth year, whereas the rate of increase in water stability for the 1944 ley was rapid for the first 4 years, then declined.

What time is required to restore old-arable soil to the physical condition of old grassland? At none of the twenty-two farms was the physical condition of old grassland reached, although on some of the very sandy soils it was approached. In Northamptonshire, other fields than the four considered had been down to grass for different periods of time, and the water stability of the aggregates from them (all sampled on the same day) are shown in Figure 5.

An old arable field (J.H. 81) is included for comparison. It is clear that more than 40 years are required to restore this soil to the condition of 110-year-old pasture. Is there any evidence that

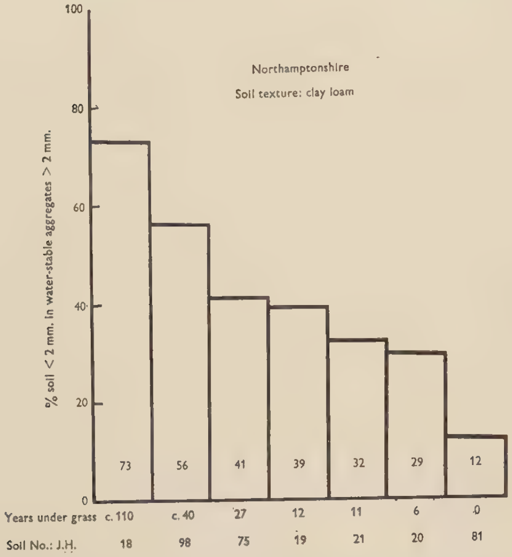


FIG. 5. Influence on water-stable aggregation of number of years under grass. Sig. diff. 5·8.

110 years had produced an upper limit in water-stable aggregation and the crumb structure characteristic of old grassland? The data in Table II suggest that an upper limit may have been reached at or before 110 years. No structural differences were observed in the field between these two pastures.

TABLE II

WATER STABILITY OF AGGREGATES FROM OLD PASTURES

Soil	Years under grass	% soil < 2 mm. in water-stable aggregates > 2 mm.
Clay loam ..	110	71·7
Clay loam ..	400	60·6

S.E. (single determination) ± 4·5; sig. diff. 7·3.

STRUCTURAL IMPROVEMENT

Time for Restoration

The experiments show that under average farm conditions and with soils ranging from sandy loams to clays, many years are necessary to restore to an old arable soil the physical condition of old grassland.

Rather different conclusions have been reached in other countries. In the U.S.S.R. the general opinion has been that structure is restored by leys in 2–4 years [11, 21, 23]. Possibly the U.S.S.R. figures refer to very sandy soils, for only on sandy soils have we obtained an I.A. approaching 100 in 3 years. Further, Russians and Americans usually quote per cent soil retained on a 0·25-mm. sieve; this tends to give a figure nearer that of the old pasture [14]. Outside the U.S.S.R. there is neither evidence for such rapid restoration nor the same unanimity of opinion. Rounce (1949) in Tanganyika could not detect any change in crumb structure of a light soil after 3 years of elephant grass. In the U.S.A. Olmstead (1946) found that after 7 years of grass the water stability of a soil was much smaller than that on virgin pasture on the same soil type with similar grasses. Jacks (1944 and 1949) concludes from a survey of the literature that soil structure can usually be restored in 2–5 years under grass.

Influence of Sward Composition

The composition of the swards was similar at all the farms, being predominantly perennial rye-grasses and white clovers. At Jealott's Hill the effect of different mixtures on the structure of a sandy loam soil has been studied. Under pure grass swards (1-year and 3-year leys) rounded aggregates developed and the furrow slice tended to collapse, giving a powdery tilth, whereas with clover-dominant swards they tended to be larger and more angular, the furrow slice not breaking down readily. Grass-clover swards tended to give an intermediate condition. The difference in behaviour has been striking on ploughing both the 1-year and 3-year leys. Differences in aggregate stability were not significant.

The relative influence of legumes and grasses has been studied by Ward (1949), who found grasses superior to legumes on sandy soils and the converse on clay soils. Martin (1944) in Uganda and Tsyganov (1948) in the U.S.S.R. found grasses better than legumes, the former finding the difference small. Ackerman and Myers (1943) found lucerne better than grasses, but the legume received more manure. Page and Willard (1946) and Baiko and Suchalkina (1950) found the effect of grasses on structure was enhanced by addition of legumes, the former using lucerne. In these comparisons there is no indication that the grasses received nitrogenous fertilizers as at Jealott's Hill. Here the comparison was between clovers (white and red) and grasses, whereas the literature usually refers to legumes, with lucerne occasionally specified.

Influence of Worms

Structural improvement under grass often appeared to be linked with worm activity. When the ley was established on old arable land, worms often numbered about 30,000–40,000 with 2,500,000–3,000,000 on adjacent old grassland. As the ley became older the worm population tended to increase, but not steadily, owing to seasonal variations in soil conditions. It is presumed that increase was related to increasing food supply. Increase in worm activity appeared to coincide with better root development.

The effect of the structure of the soil on root development of grasses and clovers at the time of ley establishment was observed on several farms. For example, some very poorly aggregated and water-unstable old arable soils were sown with ryegrass and clover and close-grazed by sheep. The soils soon became very compact and root development and ley productivity were limited, although there was a small increase in water stability. After ploughing and reseeding, however, a good tilth was obtained in the seed-bed, and vigorous leys developed. Worm activity also increased greatly and gave rise to a very porous structure, although the soil aggregates were much less water-stable than those of the old pasture. After 1 year, root development was excellent and superior to that in adjacent 50-year-old pasture, though the indications were that the continuous close grazing would prevent this being maintained.

Aggregate Stability and Soil Depth

Comparisons made between soil samples taken at different depths showed marked variations in aggregate stability, and these were related to root development. In a 70-year-old pasture in Derbyshire, for example, aggregate stability was much lower at 6–12 in. and root development was much poorer than it was at 0–6 in. where stability was higher (Table III). In a 110-year-old pasture in Northamptonshire, where aggregate stability was high at all depths of sampling, root development was good to at least 12 in. In a 6-year ley in Northamptonshire aggregate stability in the 0–6 in. layer was much less than in the corresponding layer of the old pasture, and it is remarkable that aggregate stability at 12–18 in. in the old pasture should be considerably greater than that at 0–6 in. in the ley.

That poor drainage may adversely affect structural improvement was demonstrated in an old pasture in Northamptonshire having ridge-and-furrow drainage: differences in water stability of the soil aggregates from the top of the ridge (well drained) and bottom of the furrow (poorly drained) were highly significant.

TABLE III

VARIATION IN AGGREGATE STABILITY WITH DISTANCE FROM SOIL SURFACE

Site	Type of sward	Date	% soil < 2 mm. in water-stable aggregates > 2 mm. at different depths in inches		
			0–6 inch	6–12 inch	12–18 inch
Derbyshire, silt loam	Old pasture	Autumn 1949	69·35	22·01	—
Northamptonshire, clay loam	Old pasture	Spring 1950	72·59	63·27	50·79
	Ley 1944	Spring 1950	28·84	26·23	—

There were no signs of impeded drainage in the soil on top of the ridge, whereas in the furrow the roots were rust-coated almost to the surface. Similar differences in aggregate stability were found between old pastures of like soil texture but with different drainage. The differences may be caused by poor drainage restricting root development.

Effects on Roots

Field observations of poor structure in sandy soils showed that little aggregation with fairly close packing was their chief characteristic, whereas with clay soils it was aggregation into a coherent mass with little visible evidence of effective pores.

In the sandy soils, roots were able to push their way between the sand grains and bind them into aggregates. Such aggregates were often reasonably water-stable though they were mechanically weak, and they were formed on a considerable scale in a few months.

In wet clay soils with only a micropore space, root movement was impeded; it took place more rapidly as soils dried, roots developing in the cracks. Structural improvement was slow.

In our work the most difficult soils to improve in structure were those low in coarse sand or clay but high in fine sand or silt. Where aggregates in such soils broke down, a closed structure developed through which roots could not move freely when the soil was moist, and on drying out there was little formation of aggregates, as there was little shrinkage.

It is assumed that soil aggregates slowly became more water-stable under a ley owing to protection of the clay colloids by organic colloids arising from the breakdown of organic matter.

CONCLUSIONS

Complete restoration of old arable land to the physical state of old grassland was not reached on any of twenty-two farms studied.

Rate of physical improvement of old arable soils sown to leys depends mainly on these factors:

(i) *Initial physical state of the soil.* The higher the water stability of the aggregates the more quickly can a better physical state be built up.

(ii) *Management.* This is very important. If fields are so grazed that the soil is closely compacted and root development restricted, structural improvement is greatly hindered; worm movement is made more difficult. Water-stable aggregation is frequently greater in samples taken after hay crops and periods of vigorous growth. Liberal manuring with F.Y.M. and inorganic fertilizers seems necessary to give vigorous growth. Where a soil condition resembling old grassland is required, it is probably best to plough the ley and reseed after about 4 years.

(iii) *Drainage.* In poorly drained soils, plants tend to have poor root systems and roots may be killed. Good rooting is a major factor in the physical restoration of old arable land, and bad drainage retards this process.

(iv) *Mechanical composition of the soil.* Structural changes appear to take place more rapidly in soils containing either much coarse sand or clay than they do in soils of other types.

Old arable land cannot generally be restored to the physical state of old grassland by 3–4 years in ley. On sandy loams, with free drainage restoration may take 5–10 years. On clay loams, 50 years or more may be necessary.

ACKNOWLEDGMENT

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REFERENCES

[1] Akerman, F. G. and Myers, H. E. (1943). *Soil Sci.*, **55**, 405–13.

[2] Alderfer, R. D. (1946). *Soil Sci.*, **62**, 151–68.

[3] Baiko, V. D. and Suchalkina, M. I. (1950). *Sovet. Agron.*, 1950, No. 1, 12–21 (*Soils and Fert.*, 1950, **13**, 182).

[4] Elliot, R. H. (1898). *Agricultural Changes* (now *The Clifton Park System of Farming*). (Faber, London.)

[5] Hénin, S. (1938). *Monogr. Cent. nat. Rech. agron.*, 9–69.

[6] Hénin, S. (1939). *Ann. agron., Paris*, **9**, 300–11.

[7] Hénin, S. and Turc, L. (1949). *C.R. Acad. Agric., Fr.*, **35**, 597–9.

[8] Jacks, G. V. (1944). *Jt. Publ. Imp. agric. Bur.*, No. 6, 42–55.

[9] Jacks, G. V. (1949). *Research*, **2**, 348–52.

[10] Kolodny, L. and Neal, O. R. (1941). *Proc. Soil Sci. Soc. Amer.*, **6**, 91–95.

[11] Lobanov, P. P. (1948). *Sovet. Agron.*, No. 11, 30–44 (*Soils and Fert.*, 1949, **12**, 127).

[12] Low, A. J. (1950). *Trans. Int. Congr. Soil Sci.*, **3**, 9–13.

[13] Low, A. J. (1951). *S. East Nat.*, **56**, 24–45.

[14] Low, A. J. (1954). *J. Soil Sci.*, **5**, 57–74.

[15] Martin, W. S. (1944). *Emp. J. exp. Agric.*, **12**, 21–32.

[16] Olmstead, I. B. (1946). *Proc. Soil Sci. Soc. Amer.*, **11**, 89–92.

[17] Page, J. B. and Willard, C. J. (1946). *Proc. Soil Sci. Soc. Amer.*, **11**, 81–8.

[18] Rounce, N. V. (1949). *The Agriculture of the Cultivation Steppe of the Lake, Western and Central Province.* Dept. Agric., Tanganyika.

[19] Rowles, W. (1948). *Sci. Agric.*, **28**, 558–73.

[20] Tsyganov, M. S. (1948). *Pedology, Leningr.*, 561–8 (*Soils and Fert.*, 1949, **12**, 95).

[21] Vorobiev, S. A. (1950). *Pedology, Leningr.*, 257–61 (*Soils and Fert.*, 1950, **13**, 337).

[22] Ward, H. S., Jr. (1949). *Ecol. Monogr.*, **19**, 145–71.

[23] Williams, W. R. (1949). *Principles of Agriculture*, p. 87. (Hutchinson.)

[24] Wilson, H. A. and Browning, G. M. (1945). *Proc. Soil Sci. Soc. Amer.*, **10**, 51–7.

METHODS OF PLANT PROTECTION FOR PEASANTS IN THE TROPICS

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Crop losses from pests and diseases continue to be unduly high in smallholdings in tropical countries, not so much because the peasant is unaware of the benefits to be derived from plant protection measures as because the chemicals, formulations, and equipment are often ill-adapted for the systems in which they must be applied. This paper calls attention to the problems involved and indicates ways to remedy matters.

At the Colston Symposium of 1953 [6], which was the only meeting in Great Britain ever to deal exclusively with insect control methods in Colonial territories, a stimulating controversy arose between the exponents of locally made appliances and of more elaborate mechanical equipment. A good deal of this controversy hinged on the size of the holdings on which control measures were to be applied. The sharpness of the clash, however, becomes less apparent when we consider that the word "peasant" today is applied to smallholders in all stages of social and economic development.

It is difficult to avoid becoming platitudinous on the subject of the application of plant protection methods in peasant conditions, for much rhetoric and ink have been expended on it since the end of the late war. Yet reports on the successful establishment of routine procedures in tropical territories usually end in some such statement as "it remains to be seen whether this practical method will be widely adopted in the conditions peculiar to this area." This situation certainly calls for attention, and the object of this article will be threefold: firstly, to consider in light of current ideas and experience the kinds of chemicals, formulations and equipment, and the physical systems in which they may best be applied; secondly, to discuss a few actual examples; and thirdly, to follow the problem beyond the purely technical solution of the agricultural specialist and see where we have to use the methods of other disciplines to ensure successful treatment.

Two assumptions will be made in order to clear the text of many conditional statements which otherwise would have to be introduced. It will be assumed that every reasonable effort is being made to induce the peasant to raise his basic yields by such expedients as timely land preparation and planting, good singling and weeding, mulching and fertilizing. It will also be assumed that in controlling insect outbreaks the entomologist is aware of the dangers of upsetting the ecological balance. Most practising entomologists in the tropics will by now have seen an instance of DDT doing more harm than good. They are, however, usually faced with the necessity of meeting trouble as it comes, and have perforce to leave the longer-term pursuit of the ideal of ecological control to the central research stations.

INSECTICIDES REQUIRED

On the employment of chemicals on peasant holdings our ideas must remain fluid. Dogmatic statements on the non-persistence of this or the human toxicity of that material are likely to be upset almost overnight by developments in formulation, placement or in basic chemical research. There is a nostalgic inclination towards the two first discovered synthetic insecticides, DDT and BHC. The peasant is looking for the perfect universal material—costless, harmless, foolproof, and effective against all ills. How near can we or should we approach such a standard? Working in 1947 on the development of a dust for American bollworm on cotton in Tanganyika, the writer made up a "half-and-half" DDT/BHC dust containing 5% or 10% DDT and 0·5% BHC, using a cheap DDT powder produced in Africa and a BHC concentrate imported from the United Kingdom. The practice built up in America of using high gamma-BHC component up to 3% was subsequently introduced with success, and a mixture of this kind could be a standby for many insect control purposes in tropical territories. DDT is still widely used in the control of stem borers, army worms, tobacco thrips, cacao mirids, bean fly, and a wide range of insects found in human habitations and animal shelters, notably mosquitoes and lice. It can be used with reasonable care in protecting stored foodstuffs by the residual spraying of stores, sacks and other containers.

BHC is widely known to be less toxic to human beings than DDT and is therefore more frequently recommended in connection with food. It may be mixed with grain to the limit of 2·5 p.p.m. calculated as residue in the consumable product. The writer found it outstanding in controlling the relapsing fever tick in native huts in Tanganyika, and little difficulty was found in persuading the householder to use it. On field crops BHC has probably found its greatest use by peasants in baits against locusts, grasshoppers, and crickets of various species. It has also been extensively used throughout India and south-east Asia in the form of dusts to control various paddy pests, particularly coreid and pentatomid bugs, jassids, thrips, and leaf beetles. In Trinidad and British Guiana, BHC dusts are standard hand applications for the control of froghoppers in the nymphal stage on sugar cane, and it is now being used in India on the same crop. Among other applications of this insecticide, mention might be made of the use in India and elsewhere of BHC in a mixture with manure and compost against the coconut rhinoceros beetle, which gives hope of control where owners are enlightened.

It is safe to say that a few basic dust mixtures of DDT and BHC would solve a wide range of tropical insect problems if they could be regularly applied. But many other chlorinated hydrocarbons have appeared on the scene to challenge the two established favourites. Outstanding in toxicity against broadly the same range of insects, and even more persistent than DDT, dieldrin and its pure isomer endrin are already in routine use in dollar countries, and only the fact that the acute oral toxicity to rats is 16·8 mg./kg. body weight for endrin and 90 for dieldrin against 250 mg. for DDT might weigh in the minds of entomologists in countries where the same materials are apt to be used for control of domestic and storage insects. The dangers of using dieldrin in agriculture are less than had been expected. The related aldrin, a substance of greater volatility, has been hailed as a soil insecticide useful against wireworm, termite, white grub and many insects for which BHC has been employed.

The fugitive nature of both BHC and aldrin when exposed on foliage or other open surfaces in the tropics has surprised observers from temperate countries. In Nigeria an effective life of less than one week for BHC under cover in warehouses has been determined. In open sunlight on foliage it is probably less persistant even than this.

Much has been said of the drawbacks of the organophosphoric insecticides of the parathion group, but development in this field is so rapid that we can be confident that the chemist will very soon give the world a practically non-toxic equivalent of parathion. Parathion, EPN, chlorothion and related compounds are being tried out on a wide scale on peasant holdings in Japan and south-east Asia against rice insects, stem borers and paddy bugs. The new remarkable L13/59 (Dipterex) has an acute oral toxicity of about 1200 mg./kg. to humans together with a toxicity to house flies commensurate with that of parathion. Possible peasant applications of these materials are in the control of scales, mealy bugs, aphids and leafhoppers. Hopes are also being raised of replacing the older types of fruit fly baits, which many entomologists have found capricious or ineffective, with baits containing parathion or its relatives. It has in fact been necessary in Southern Rhodesia to issue a caveat on this subject [4].

The true systemics may at present be discounted for use by the small grower in the tropics, but this picture may be changed at any moment.

Finally, a word on the older insecticides of vegetable origin may still be said within the context of peasant agriculture. While pyrethrum, which is not a true tropical crop, is unlikely to enter the picture except in the protection of stored foodstuffs, both nicotine and derris are produced and used locally by small cultivators. Where smallholdings include tobacco, tomatoes, European potato, and vegetables the writer has found many uses for fresh derris root, bruised into water to make a spray fluid of considerable versatility; ants, aphids and small stem-boring or leaf-eating caterpillars are well controlled in such situations with minimal cash outlay.

FORMULATION

Turning now to the important subject of formulation, the oft-repeated objection to sprays on the grounds that water must nearly always be carried some hundreds of yards in skins or kerosene tins is real enough to preclude all possibilities but the straight dust or the low-volume spray or mist-blowing concentrate. The wettable powder will retain its popularity in urbanized areas where water is available and where there is considerable demand for residual spraying of houses and stores. The production of cheap dusts with only 5–10% of imported concentrates has been developed in some countries, notably in East Africa, where natural deposits of diatomite are commercially exploited for various purposes. In many countries, however, filler materials exist only as remote deposits of crude minerals, such as talc, rock phosphate and volcanic ash, and the capital cost of extraction and preparation puts them out of court in relation to insecticides. In these places the merits of miscible liquids will receive special consideration.

One further point in evaluating rates of application of dust formulations is the wide difference in bulking density of the fillers. A fair coverage of a 1-acre cotton plot may be obtained with 10–12 lb. of a diatomite dust, whereas if the same effect is to be produced with fuller's earth or talc 30–40 lb. would have to be used. It is essential to make this clear in directions for use.

There is often heard a demand by entomologists for a more adhesive dust, but this is probably a contradiction in terms, for the first thing a dust particle is going to adhere to is its neighbour, and a dust which would be adhesive enough to resist wind and rain would clog even crude forms of dusting equipment.

Of miscible liquids it is proposed to say little, for their formulation is a highly technical and properly commercial process and must remain so if all the desirable properties, not the least of which are long shelf life and non-corrosiveness to containers, are to be achieved. Here the comparatively non-toxic DDT and gamma-BHC miscible oils and liquids will have the advantage for handling, in concentrated form, over dieldrin and parathion. One of the chief problems in the use of these formulations, which are sprayed at 10–15 gal./acre, is increased phytotoxicity from the organic solvent.

In many places sufficient water is available and home-made formulations can be encouraged. The emulsification of DDT solution in kerosene by stirring with a boiling solution of local washing soap provides a safe and effective insecticide for the *Antestia* bugs of coffee in northern Tanganyika [5]. The writer found a simple way of emulsifying Tarakan aromatic diesel oil by dropping it into a thin clay/water mixture churned by means of a stirrup pump; the resulting mayonnaise emulsion had a ready sale in Mauritius at a few pence per gallon to small planters for ant and aphid control diluted to ½–1% of oil and applied by stirrup pump [2]. Many improvisations of this kind could be instanced, the most recent of which is the making of Bordeaux mixture from copper sulphate and carbide for control of black pod of cacao in western Nigeria. But no one would be more pleased than the specialist in the field if manufacturers would make these efforts unnecessary by producing cheap, reliable materials, since both supervision and labour are expensive items in carrying out precision operations, such as spraying, in the tropics.

EQUIPMENT FOR APPLICATION

On the vexed question of equipment for use in tropical peasant conditions the writer would ensure that each class of appliance is considered only in relation to the system in which it is to be used.

In the most primitive class, the various types of bag and pepper-pot dust shaker, with that noteworthy improvement the Swaine concertina dust blower improvised from a 7 lb. sweet tin and a piece of car inner tube, seem quite suitable for the ½–1 acre patch of maize, rice or cotton. Where the cash return of the crop is but £6 to £8 yearly, or where accurate placement into the funnel of young maize plants or round the base of sugar cane stools must be ensured, it is probable that no more elaborate means are necessary. It is very desirable that containers should hold enough to cover an easily remembered portion of the crop, whether it be 10, 100 or 1000 plants. In the wet spraying group there has appeared a simple form of low-volume nozzle, resembling a tee jet and incorporating a non-return valve, which can be screwed on to a bicycle pump or soldered or fixed into a locally-made pump of tin or bamboo. Such pumps could be charged from a petrol tin containing the spray fluid. Although equipment of this kind may be somewhat inefficient, the cost of any of the foregoing items is only about 5s.

Widely separated by its price range of £2 to £4 is the next class, which includes the stirrup pump. Purchase can therefore be contemplated only by the peasant who can buy his agricultural needs through a producers' co-operative, a land settlement scheme or an agricultural credit society, where special discounts, time payments or recoupment from crop sales are possible. The bellows duster is regularly used for cacao dusting against mirids on plantations in the Belgian Congo and has proved handy in dusting small planters' pepper against the bug *Dasynus piperis* in Banka island. The trombone sprayer, used for many years in the spraying of anti-mosquito oils, has recently been improved to include powerful double action; it provides for the first time the possibility of low-volume spraying, using as a reservoir a simple knapsack container that can easily be made locally at an all-in cost of under £4. In a big settlement scheme, equipment of this kind could be loaned and regarded as expendable in the initial stages. The disadvantages of the trombone sprayer at the moment are the numerous loose pieces—valve balls, springs, filters, washers, swirl and nozzle plates—whose replacement frequently baffles even the enlightened layman and the loss of which would certainly discourage the simple peasant in his efforts at chemical plant protection.

The pneumatic knapsack sprayer and the rotary duster are familiar weapons in the armoury of any government entomologist or plant pathologist. Improved by well-meaning and ingenious theoreticians, often to the extent of a 50% price increase, this class of equipment is now in the £10 to £20 range and hence will not be available to the small farmer except on loan from some central agricultural organization or as part of the equipment of government-treatment teams. Recently, however, in the more highly developed cash economy of west African cacao, arrangements have been made through the Department of Agriculture in western Nigeria for the supply of knapsack sprayers to farmers who have qualified by means of a special course in their use against black pod disease. This excellent initiative has already proved that the more enlightened peasant will maintain and use simple mechanical equipment as part of his cultivation routine. Before leaving this sketchy reference to an old friend it may be said that the detachable or the separate lever-action headland pump for charging knapsacks is a real benefit in saving human effort and weight. The refinement, though marginal for peasant use, seems to be well established in tea gardens in blister blight spraying.

The rotary duster, a clumsy implement in the £12 to £15 class, is an object of endless criticism, most of it destructive. Dr. Kearns (1954) sums up realistically as follows: "The demand for a well-designed hand rotary duster comes up at regular intervals. Again, it must last for ever, stand up to corrosive powders, never require repair and cost nothing." More serious, in the writer's opinion, are the almost universal failure to prevent clogging and the low centre of gravity, producing fatigue in use.

The introduction of the internal combustion engine into peasant holdings for plant protection work must await the discovery of a way of providing capital assistance to the farmer. There is no lack of well-designed machinery for the row crop, from the low-volume wheelbarrow to the tractor-mounted sprayer now widely used in temperate countries for weed control. Apart from the two-stroke, which can be a nuisance owing to its capricious starting habits, the internal combustion engine survives remarkably well in the tropics, and the organization of maintenance is reasonably easy, though always costly in the initial stages. There may be a distant future for mechanical juggernauts in aggregated peasant agriculture, but two particularly difficult obstacles are manipulation of large equipment in the sticky conditions of the tropical growth season, and the large capital tied up in the many units necessary to cover any sensible proportion of the holdings in big countries, as for example Nigeria or Tanganyika.

ADMINISTRATIVE PROBLEMS

The chief types of peasant systems into which plant protection practices may have to be fitted are:

1. Scattered groups of field crops in plots of ½–1 acre, often separated by miles of bush as in Africa, and the patchwork of irrigated fields in the crowded countries of south-east Asia. There is little ability or incentive to apply methods involving any cash outlay. At most these plots could be subjected to a moderate degree of aggregation in which groups of peasants under the advice of a trained member of their own ethnic group might agree to grow larger continuous areas of one crop in a rotation.
2. Closely knit tribal communities growing one main crop, such as cocoa, coffee, bananas or coconuts. Village communities in the Indian sub-continent would seem to fall into this category. If the cash economy has proceeded to the stage of co-operative marketing and buying of fertilizers and insecticides, progress by demonstration seems promising.
3. Well-defined peasant groups living in areas where improvement schemes, mainly under the aegis of governments, are in operation. Land settlements made in the fight against sleeping sickness, soil erosion and leprosy are examples in which the use of the more elaborate forms of spraying and dusting by trained teams might be introduced.

Other considerations beset the entomologist or plant pathologist when he is faced with the problem of applying the methods of his choice to the realm of the peasant. Even when he has reduced the supply of chemicals and equipment to a routine and has overcome the physical problem of timely and efficient application to the crop by the individual, he will still be called into consultation if the extension services find that his otherwise unexceptionable control method fails to become widely adopted. What shall his advice be?

Let us picture the scientist trying to analyse the motives of the potential user of his methods. Has he demonstrated sufficiently by local experiment the source and amount of regular and avoidable loss? Why should a man become and remain interested in carrying out a control routine? To the first question the scientist must answer that such a demonstration has rarely been possible. Speaking of the extent of damage by *Lygus* to the cotton crop of Uganda and of its assessment by plot spraying methods, Geering (1954) says: "Until standardized experiments of this sort are conducted on peasant crops over a number of years in many representative localities one will not know the answer to the question 'How much loss, how often, in how many places?' But until they are carried out, the true status of this type of insect pest, and indeed of most others in African peasant agriculture, will remain in the realm of speculation."

The danger of speculation in the field of peasant agriculture has become obvious from the failure of a number of projects of colonial development, largely owing to the absence of information derived from pilot schemes. Risk-capital must be provided if the peasant is ever to be raised above the subsistence line. Here then is the first maxim for the plant protection officer: the cost/potential benefit ratio of control measures must be demonstrated in order to attract the resources in labour and money necessary to implement them. To some extent this has been done for the cacao farmers of the Gold Coast and Nigeria in respect of the capsid bug and black pod disease. Among the Wachagga tribe of Kilimanjaro the merits of regular coffee spraying against *Antestia* have spread from a contemplation of European farming practice. In the lower delta region of Egypt the small farmer is now fully conscious of the benefits of regular dust treatments for cotton leafworm, *Prodenia litura*. It is superfluous to multiply these examples or to stress the need to make clear the economic reasons for control activities.

The further necessity to unlock the psychological barrier to a ready and sustained effort on the part of the individual has only recently begun to be realized. Incentives, motives, and intellectual and physical limitations must all be considered. It may be easier to persuade a peasant to adopt a method made attractive or distinguished by novelty or fashion than to make him change an ancient error in his agriculture. We might, for instance, study the form, nature or colour of cherished objects and by making our equipment and chemical packages correspond with them promote their use. An example of simple sales psychology of this kind is the branding of packages of razor blades with a rampant lion, signifying strength. Such stuff is not for the scientist, but with the aid of the anthropologist and the salesman an approach on these lines may be of value. A more practical way of raising incentive, in use in Nigeria to extend cacao spraying, is to award to each grower who completes a course in knapsack spraying a certificate that permits him to buy a sprayer and chemicals on special terms. This gives some guarantee of competence and of will to give the method a serious trial. In the Gold Coast the problem of cutting out trees suspected of infection by swollen shoot disease was solved by the imaginative use as agents of local men who had been convinced of the necessity of the operation. By posters, films, playlets and by broadcasting much could be done in areas where control measures are known but where physical, economic, social and psychological barriers exist. The scientist can surely make his voice heard in the councils of those who have to take the responsibility of implementing scientific methods. By increasing the opportunities for the exchange of ideas and progress reports between scientist and administration, much control work can be rescued from oblivion and the research worker from frustration.

REFERENCES

[1] Geering, Q. A. (1954). *Rep. 6th Comm. ent. Conf.*, 83–6.

[2] Jepson, W. F. (1939). *Rep. Dept. Agric. Mauritius*, 1938, 40–51.

[3] Kearns, H. G. H. (1954). "Spraying Technique and Machinery," *Insecticides and Colonial Agricultural Development. Proc. 6th Symp. Colston Res. Soc.*, 1953, 141–50. Butterworths, London.

[4] Mossop, M. C. (1955). *Rhod. Agric. J.*, **52**, 228–33.

[5] Notley, F. B. (1949). *E. Afr. Agric. J.*, **15**, 25.

[6] Wallace, T. and Martin, J. T. (1954). *Insecticides and Colonial Agricultural Development. Proc. 6th Symp. Colston Res. Soc.*, 1953. Butterworths, London.

CACAO DISEASES

S. H. Crowdy and R. S. Elias

Cacao has been described as a crop with a bright future largely because the demand for cocoa and chocolate continues to rise and prices have so far been very profitable. But serious diseases keep yields low and menace the prosperity of communities that depend on the crop for a livelihood. It is suggested here that cacao diseases can be controlled by the ordinary methods of plant pathology if adequate research is given to the problem.

An increasing amount of attention is being given to the control of diseases that take a heavy toll of cacao and threaten the future of this valued plantation crop. The situation is briefly discussed here, with a few introductory notes on the plant and its cultivation.

The cacaos of commerce are derived from varieties of *Theobroma cacao*. Under natural conditions this species is an under-story tree in the rain-forests of the Amazon-Orinoco basin. It is a tropical crop normally cultivated in warm, damp regions in the rain-forest belts but extending into far drier zones, as in the fringing forests beside rivers on the borders of orchard savannah regions.

Plantations are established either by sowing in the field or by transplanting seedlings or rooted cuttings raised in nurseries. Spacing ranges from the random 3–5 ft. of the West African peasant, which becomes thinned by competition and disease to a mature stand of about 700 trees an acre, to the 15 × 15 ft. plant in Ceylon. A satisfactory density is probably about 500 trees an acre. The advantage of the dense plant is that the canopy closes quickly and the shade becomes too heavy to allow weed growth. Additional shade is usually provided either by selective thinning of the forest cover when the site is cleared for planting, or by inter-planting trees of suitable species. The tree grows to a height of 20–30 ft., and the flowers and fruit are carried on reduced inflorescences on the trunks and larger branches. The fruits, called pods, are hard-shelled and about 9 in. long; they contain 20–40 seeds or "beans" embedded in a mucilaginous pulp, and the beans are fermented and dried before shipping as dry cocoa.

Yields vary greatly with age of tree, stand, and conditions of growth; another factor is that self-fertile trees produce much more than self-sterile trees. At present nearly all the world's crop comes from trees raised from seed, and cacao of this kind may give poor yields. Plantings in the Gold Coast are predominantly of a self-fertile type, and the yields of dry cocoa average about 650 lb. an acre. In Trinidad, where many of the trees are self-sterile and a high proportion may be unthrifty for other reasons, yields from the best soils are only about 500 lb. and poor soils may give half this figure; but, by planting selected self-fertile clonal material, yields of 1000–1400 lb. an acre have been obtained in the 13th year.

The importance of the crop is shown by the world export of 755,000 tons of cocoa in 1953, valued at about £300,000,000. Rather more than two-thirds of the total is low-grade material from West Africa, mainly the Gold Coast and Nigeria. The balance is derived chiefly from Bahia in Brazil and other areas in tropical America.

MAJOR DISEASES

Estimates of crop losses due to disease are notoriously unreliable, but it has been suggested that out of a potential annual crop of one million tons about 200,000 tons are lost to diseases and pests. The chief losses are: 70,000 tons from fungus-infected capsid lesions, 50,000 tons from virus diseases, 50,000 tons from black pod, and 20,000 tons from other diseases.

Virus Diseases

Records of unexplained cacao deaths in the Gold Coast, which were probably due to virus infection, occur as far back as 1922; but fourteen years elapsed before this dieback was recognized to be of major importance, and not until 1940 was the virus nature of this disease finally established. More recently virus infections have been recorded throughout the main cacao areas in West Africa, Trinidad, Venezuela and Ceylon.

A number of different viruses are involved, and several strains of each may occur, so that a general description of symptoms covers a variety of conditions. Virus infection of cacao is usually accompanied by yellow mottling of the leaves and vein clearing, due to the reduction in chlorophyll in the adjacent leaf tissues. Healthy young cacao leaves are frequently red or pink, but virus-infected ones may show a darker red. There may also be some malformation of the leaves. Stem swellings, from which the name "swollen shoot" is derived, are symptomatic of some of the West African viruses (Figures 5 and 6). Dieback and reduction in yield may be severe, and infections with virulent strains may kill trees in two or three years (Figure 4). The diseases do not appear to be transmitted either through seed or through sap; the main vectors are species of *Pseudococcus*.

Losses due to virus disease may be very severe: the yield of an 8-acre plot in the Gold Coast was reduced from about 4400 lb. to 600 lb. of cocoa in about six years, and the gravity of the situation can be appreciated when it is realized that the greater part of the West African crop is threatened with infection. A significant feature of the West African problem is that the diseases occur naturally on forest trees and have spread to cacao from this reservoir.

The chief method of control is eradication of infected trees. This is effective and not too extravagant if the outbreaks are discovered early enough, and if all infected trees are removed and continuous inspection is maintained. With large outbreaks it may also be necessary to remove apparently healthy contact trees. In the Gold Coast a cutting-out campaign sponsored by the Government has been in progress since 1945, and by 1952 over sixteen million trees had been removed. Some attempt has been made to control spread of the disease by using a systemic insecticide to kill the mealy bug vectors on trees at the edge of the outbreaks. Although this can keep the trees free of vectors, the method does not seem to have found general favour. Another way of reducing the devastating effects of these diseases is to inoculate threatened trees with mild strains which may protect against the effects of the more virulent types; unfortunately the trees are proofed only against a few strains, and they remain as reservoirs of viruses that may revert to virulent types. Plant breeding also provides an approach to control, and genetical resistance to strains now common has been observed.

Witches' Broom Disease

Witches' broom disease, caused by *Marasmius perniciosus*, which was first recorded in Surinam at the end of the last century, is now a common trouble throughout the main cacao areas of South America with the exception of Bahia. The affected areas do not produce massive tonnages of cacao, hence overall losses are far smaller than those from virus diseases; but they are the main producers of high-quality cacao, and there is the ever-present risk of spread to Bahia, where the effect might be disastrous.

The fungus infects the young growing tissues of shoots, flowers and fruit, causing gross hypertrophy: infected vegetative buds develop into fattened watery shoots; infected flower clusters produce malformed flowers, large leafy shoots and deformed parthenocarpic pods. These infected organs dry out after a few weeks and remain attached to the tree. Pod infection, which can occur at any age, results in marked deformity of the younger pods, and though external symptoms may be less evident on old pods the internal damage is so severe that total loss of crop is usual. Sporophores can be produced from all infected tissues, usually after a dormant period during which the tissues appear dead, and the spores released from them are the only means of spread.

It is difficult to assess the losses due to this disease, as damage from continued infection becomes apparent only over a period of years. The immediate loss of crop may be measured by the extent of pod infection, which is frequently 10–20% and may be as high as 70%.

Sporophore formation depends markedly on weather, and it is completely inhibited when conditions are dry; moderate moisture for prolonged periods provides ideal conditions. Since infection demands the presence of both susceptible tissue and active sporophores, its incidence is seasonal. Observations made in Trinidad suggest that the disease could be controlled by removing all the witches' brooms twice yearly, yet large-scale trials have failed to show a practical control by this method. Some control has been obtained with copper sprays, and sodium pentachlorophenate and dinitro-*o*-cresol have been reported as inhibiting sporophore production.

Black Pod and Monilia Pod Rot

Phytophthora palmivora causes a pod disease, known as black pod, and a stem canker (Figure 2). Pod infection can occur at any time during the development of the pod, and the fungus is not necessarily a wound parasite. A film of water on the pod is necessary to infection, so that the disease is serious only in wet areas. Unlike the fungus which causes witches' broom disease, *P. palmivora* develops extensively in the walls of the fruit before damaging the seed, hence pods that look badly diseased may yield marketable seed if infection occurred at a late stage of pod development. In the Gold Coast and in Trinidad an infection of 15% of the pods is common, though the proportion may rise to 50% or more in badly affected areas. Such figures, however, do not give a true picture of crop loss: thus an experiment in which pod infection was reported as 15% showed a reduction of only 5% in weight of wet cacao when compared with a Bordeaux-sprayed block in which pod infection was 2%. *P. palmivora* may form cankers either by direct infection of the stem or by growing along the pod stalk into the stem; in the second case infection is chiefly of the flower-bearing parts, and this reduces the fruiting capacity of the tree. These cankers heal if left unattended and are probably of minor importance in well-grown cacao.

Spraying the pods with copper fungicides has proved of value (Figure 1). In Nigeria application of 1% carbide Bordeaux mixture at three-week intervals has reduced infection from over 60% to around 6%; in the Gold Coast, where black pod incidence is on average much lower than in Nigeria, the same technique of copper spraying has so far failed to give an economic measure of control. Black pod may also be controlled effectively by frequent picking and removal of diseased pods; but each picking must produce a sufficient bulk of cacao to permit adequate fermentation, and the method is suitable only where the cacao areas are large enough to ensure this. Trees resistant to *P. palmivora* have been reported.

The pod rot caused by *Monilia roreri* was first recorded in Ecuador, where it was responsible for a loss of 40% of the pods. It is now known to occur in the wet districts of Colombia, Brazil and western Venezuela, but is absent in the main cacao area of Bahia. Pods are susceptible only in the earlier stages of growth. In diseased pods the beans are enveloped in a watery mass and the pods are heavier than healthy ones. They yield no crop. Spraying at intervals of 7–10 days with sulphur, copper oxide or nabam has reduced pod infection from 17% to 2% in Ecuador.

Dieback and Canker

Cacao dieback has been associated with unfavourable growing conditions and mechanical damage from insect attack, falling forest trees and canker. Several weakly parasitic fungi—notably *Botryodiplodia theobromae* and *Calonectria rigidiuscula*—infect the damaged trees. Control lies in correcting the predisposing conditions.

In West Africa *C. rigidiuscula* and *B. theobromae* are of special importance because they can infect lesions formed on cacao shoots by the feeding of the capsid bugs *Sahlbergella singularis* and *Distantiella theobromae*. The toxic saliva of these bugs destroys the tissues around the feeding punctures, and the lesions so formed may kill very young shoots, though mature shoots soon recover even from intense attacks. Should the lesions become infected by fungi, however, deep open cankers develop and death of the shoot may result. General dieback may follow infected capsid attack, and patches of moribund and uneconomic trees in the cacao result. Damage frequently kills young trees and, if widespread, may make it impossible to establish new plantings. This poses a particularly serious problem in the Gold Coast, where maintenance of the industry in the face of the ravages of virus disease depends on the establishment of cacao in new areas and on the replanting of areas from which virus-infected trees have been removed. A loss of about 20% of the Gold Coast cacao crop has been attributed to this complex.

Control of the trouble could be achieved by killing the insect or the fungus, or both. Although trees resistant to *C. rigidiuscula* attack have been reported, the greatest success up to the present has been gained by measures against the insect vector. Young cacao can be protected against capsids by painting or "spray painting" with 1·25% DDT spray, but large-scale experiments which have been in progress in the Gold Coast for the past two years or more have resulted in the widespread use of γ-BHC emulsion sprays, not only for young cacao but for mature trees as well. Low-volume mist blowers are used to apply 4 oz. γ-BHC/acre to mature trees, and two applications in a season are sufficient to clean up capsid infestations and effect regeneration of the canopy.

DISCUSSION AND CONCLUSIONS

From this account of cacao diseases prospects for the crop do not seem to be very encouraging. Each of the main cacao areas suffers from or is threatened by a major disease, and yields everywhere are low in consequence. It thus becomes an urgent problem to find ways and means of maintaining cacao production in the face of these difficulties. Among the ways of achieving this are:

1. Extension of cacao growing to areas not yet threatened with disease.
2. Breeding of disease-resistant varieties.
3. Development of conventional disease control methods.

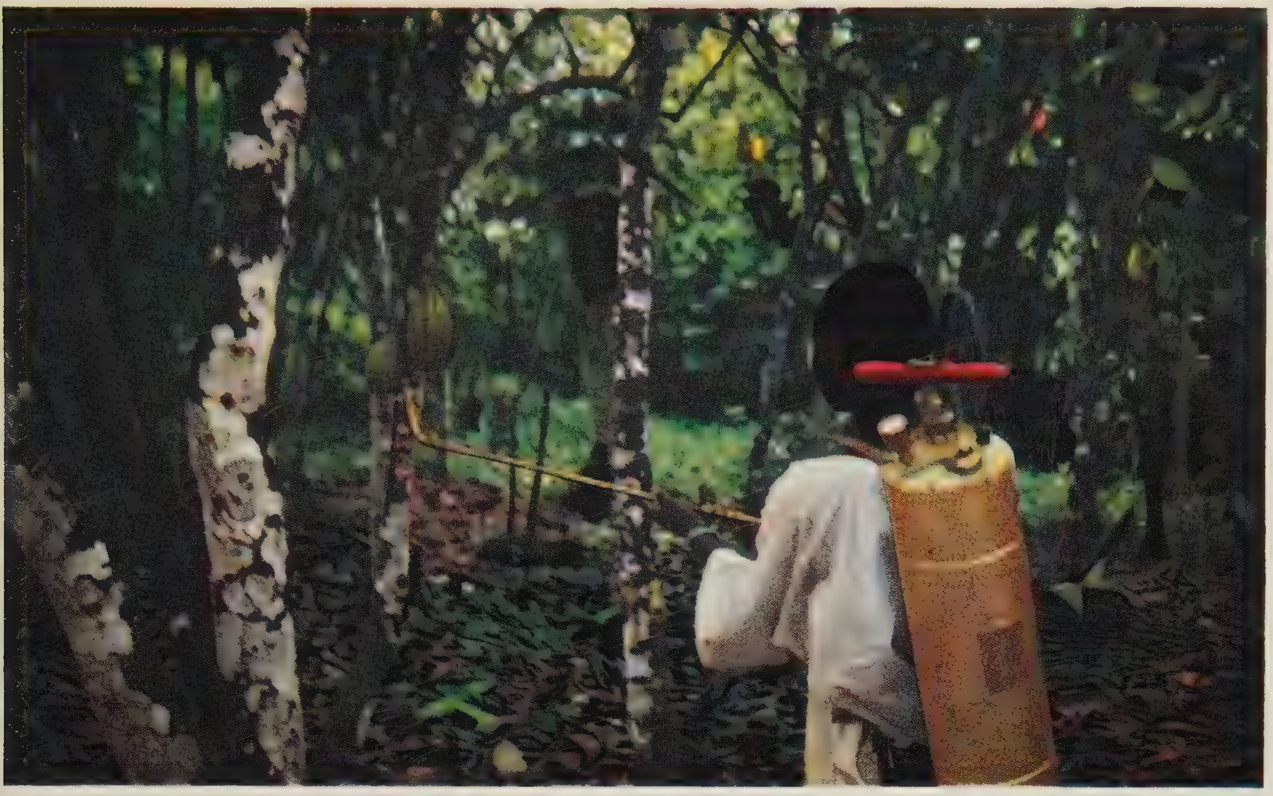


FIG. 1. Spraying cacao with Perenox against black pod disease in western Nigeria using a Myso 159 pneumatic knapsack sprayer.

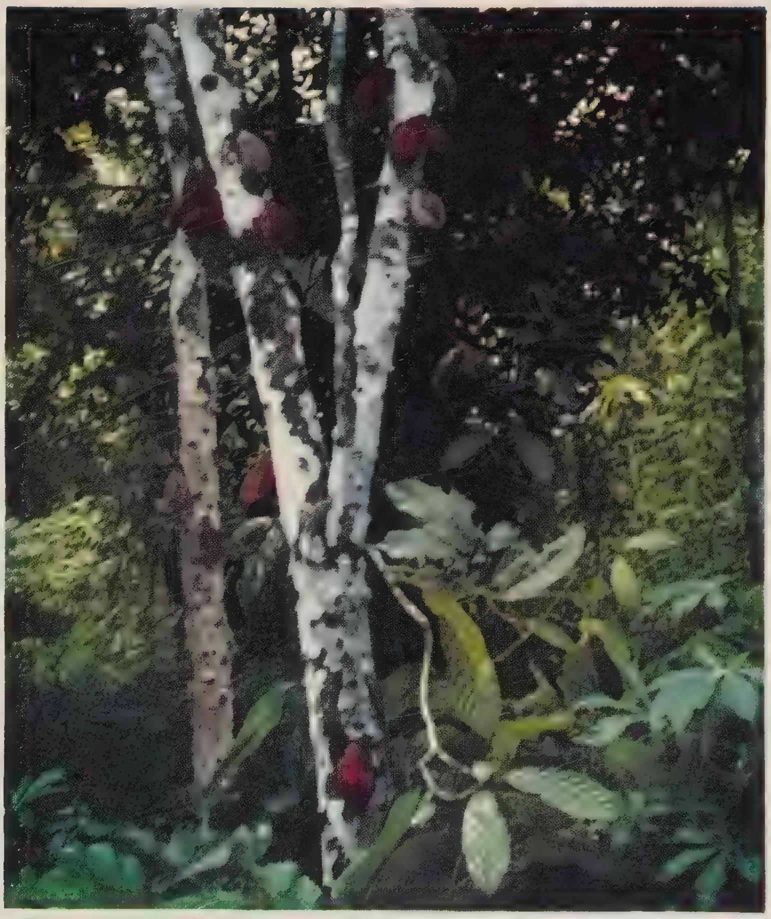


FIG. 2. Cacao pods heavily infected with *Phytophthora palmivora* in western Nigeria.

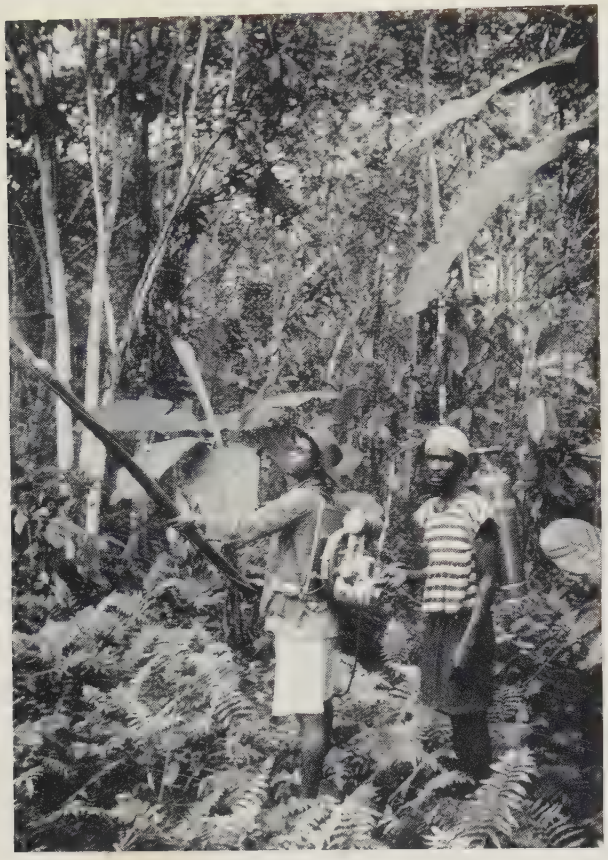


FIG. 3. Spraying cacao in the Gold Coast, using the Kiekens-Dekker mist blower.

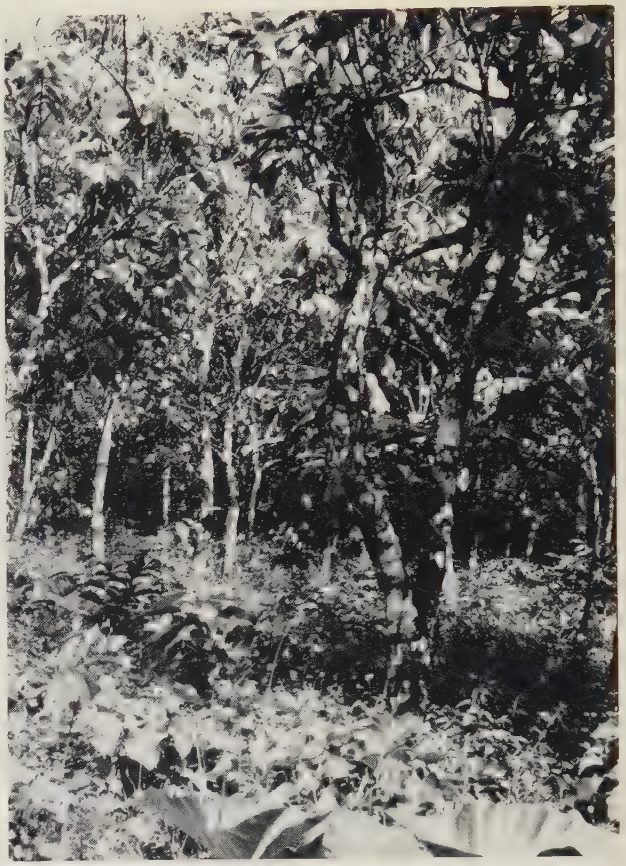


FIG. 4. Destruction of canopy of cacao by swollen shoot in Nigeria.

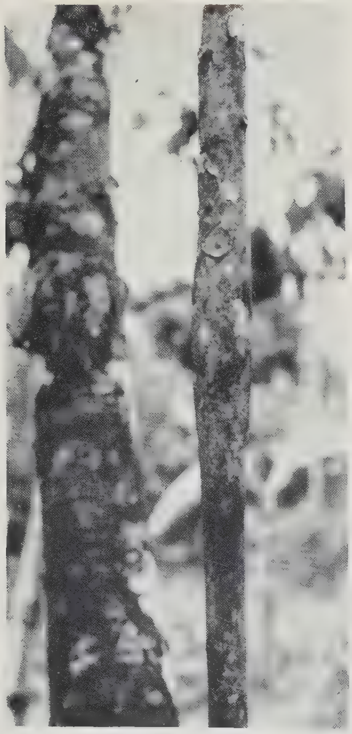
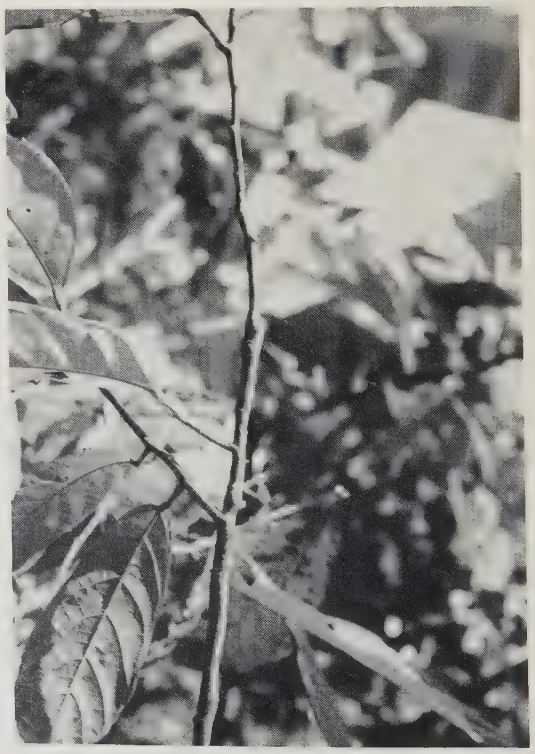


FIG. 5 (left). Symptom of swollen shoot on young cacao branch.

FIG. 6 (right). Symptom of swollen shoot in sucker or chupon of cacao.



If maintenance of world output were the only objective, cultivation in new regions might be the answer. But this ignores the dislocation of the economies of countries now dependent for a large part of their prosperity on the cacao crop, and even if adequate and suitable areas for planting did exist there is no guarantee that the crop would remain free of disease. Indeed, experience indicates that sooner or later serious disease will develop. In West Africa the viruses and the capsid-fungus complex involved were indigenous to the cacao areas, and they soon attacked the introduced crop with devastating effect. The recent record of a cacao virus in Ceylon is at least a warning that a disease problem similar to that of the Gold Coast may develop elsewhere.

Breeding for disease resistance is an approach that offers some prospect of success, for in populations of the genetically heterogeneous commercial cacao a degree of resistance has been found to all the major diseases. At best, however, the influence of these resistant types on total production will not be felt for many years. Another reason why too much reliance should not be placed in a programme of breeding for disease resistance is that genetic variation is possible in the pathogen, the short life cycle of which lends itself to the rapid propagation of variants. The bewildering assortment of cacao viruses and their strains may be evidence of the plasticity of these pathogens. In view of the large part that the breeding of resistant varieties now plays in cacao research it may be instructive to note the course of the intensive breeding programme against stem rust of wheat, in which, during the last fifty years, varieties have been repeatedly bred for resistance to current strains of rust, the resistance of each having broken down following changes in pathogenicity of the fungus. Leaf rust of wheat presents a similar picture: 156 strains of the fungus causing this disease are now known. Because new strains are distinguished by differential susceptibility of host varieties, they are revealed only by breeding and selection for resistance. This picture might well be repeated in breeding resistant cacao with the added problem that it takes many times longer to develop and distribute resistant varieties. With present techniques, strains of the pathogens will not be recognized until resistant cacao clones are known and have been distributed.

As the difficulties in establishing new cacao areas and in distributing disease-resistant types may prove insuperable, the onus of safeguarding production falls on conventional methods of disease control. These have yielded grounds for subdued optimism.

Cultural methods provide the first defence against virus disease, and production in severely infected areas can be kept at a high level by careful inspection, eradication of diseased trees, and replanting. Further, it is possible to reduce the incidence of such diseases as black pod and monilia pod rot by cultural practices designed to provide a drier environment for pod development, though the effect of these measures is necessarily limited. In theory witches' broom disease could be reduced by cutting out diseased tissue and pruning, yet in practice this has not proved satisfactory.

Chemical treatments have been effective against black pod and capsid attack: both troubles, and perhaps witches' broom and monilia pod rot, are controllable by protectant spraying, and the problem has become one of selecting the most effective chemical and devising methods of application suited to the conditions in which cacao is cultivated. Witches' broom disease is less easily tackled because the closed tree canopy necessary for weed control makes it troublesome to spray the young shoots at the tree tops, and the nature of the infection cycle may make protection difficult. In spite of this some improvement has been reported from copper spraying. The object of cutting out diseased tissue, which is to break the infection cycle by preventing spore formation, may also be achieved by spraying with certain of the newer fungicides: some success in preventing sporophore growth has been reported with sprays of sodium pentachlorophenate and dinitro-*o*-cresol, and further work on this line might well be rewarding, but treatments would have to be tested over wide areas to ensure an adequate reduction in the density of *M. perniciosus* spores.

It is probably fair to say that all the cacao diseases can be controlled by conventional plant pathological methods, and it may well be that the efforts of the plant breeder would best be directed towards providing high-quality and high-yielding types which under cultivation will yield profits large enough to support an adequate disease control programme.

ACKNOWLEDGMENT

We thank Dr. G. Watts Padwick and the Commonwealth Mycological Institute for permission to use the photographs illustrating swollen shoot disease in Figures 4–6.

WEEDKILLER TRIALS ON LALANG IN MALAYA

H. P. Allen and W. N. Smith

How to eradicate perennial grasses such as lalang is one of the main problems of the planter in the tropics. The traditional method of hand digging is now far too costly, ploughing is seldom feasible, and spraying with total weedkillers has not given good results without the risk of injury to crops. Safer chemicals are being sought and it seems possible from trials now in progress in Malaya that success might yet be achieved.

Few weeds cause more trouble in the cultivation of plantation crops in the Old World than the grass known commonly as "lalang" in Malaya or "illuk" in Ceylon. Botanically it is *Imperata cylindrica*, a perennial grass with very strong and extensive rhizomes, and though it can be found in many tropical, sub-tropical and even warm-temperate areas, it is nowhere more aggressive than in Malayan rubber plantations. Here it exists as a twofold problem: as "sheet" lalang it rapidly invades and completely takes over land that has been burnt and cultivated land that has been abandoned; as "sporadic" lalang it grows in planted rubber where the trees do not shade it out. It competes severely with young rubber trees for water and plant food, and must therefore be removed from land required for planting and kept in check thereafter.

Planters have been waging a desperate battle with lalang over the years and are always anxious to try out any method of control, cultural or chemical, which shows promise. Where land due for planting and infested with sheet lalang is flat and even, the plough can deal effectively with the weed; but on very many estates ploughing is not a practical proposition, and hand cleaning by "changkolling" (hoeing) and removing the rhizomes by hand, though quite common before the 1939–45 war, is now totally uneconomic. There remains chemical control, and two main chemical treatments have been used on a commercial scale in recent years. The first is the multiple application of sodium arsenite as a spray. Eight or ten sprayings, each of 15 lb. As_2O_3 per acre in 60 gallons of water, are carried out on the lalang (sheet and sporadic) at intervals of 10–14 days, until growth is so weak that routine patrols can deal with it. This is done by native workers using knapsack sprayers. Sometimes the patrol work consists of a few rounds in which the remaining lalang leaves are wiped with a rag soaked in aromatic oil. The second method is that of multiple application of a herbicidal oil using the same principle as with sodium arsenite, i.e. frequent defoliation of the lalang.

Of the newer herbicides available in Malaya after the second world war, which had shown promise in Europe and America, it seemed probable that sodium trichloroacetate (STCA) might prove most effective for eradicating lalang. In 1952 I.C.I. (Malaya) Ltd. treated small plots of sheet lalang with STCA at rates equivalent to 100, 200 and 300 lb./acre and compared these with plots treated with ammonium sulphamate and sodium thiocyanate. The results were encouraging: 90–100% of the lalang was eradicated; in one block the lalang was eventually succeeded by *Mimosa* and straits rhododendron (*Melastoma polyanthum*); sedges (*Cyperaceae*) succeeded lalang in the other blocks, which were, a year later, recolonised by lalang from seed.

These trials led to several others, which included the application of two successive sprays at half the original rates, and also comparison of the effect of spraying slashed (cut) and unslashed lalang. Early in 1953 estate trials were begun. Examination of these trials in August of that year showed that a single application of STCA at 120–150 lb./acre would eradicate 85–95% of sheet lalang. In some areas, particularly on roadside verges, one application of 100 lb. STCA/acre was just as good. Generally speaking, two successive applications at half this rate were ineffective, and it seemed that the chemical acted better on unslashed than on slashed lalang.

A disadvantage of STCA, besides its high cost, is that it is liable to damage rubber. Preliminary trials had indicated that mature rubber was not affected by relatively large rates of STCA applied on lalang under the trees, but extended tests showed that young rubber trees and coconut palms were severely defoliated or killed by 224 lb./acre. More recently it has been found that even 112 lb./acre will defoliate mature rubber.

Clearly a safer chemical was needed, so in February 1953 a trial was laid down on lalang

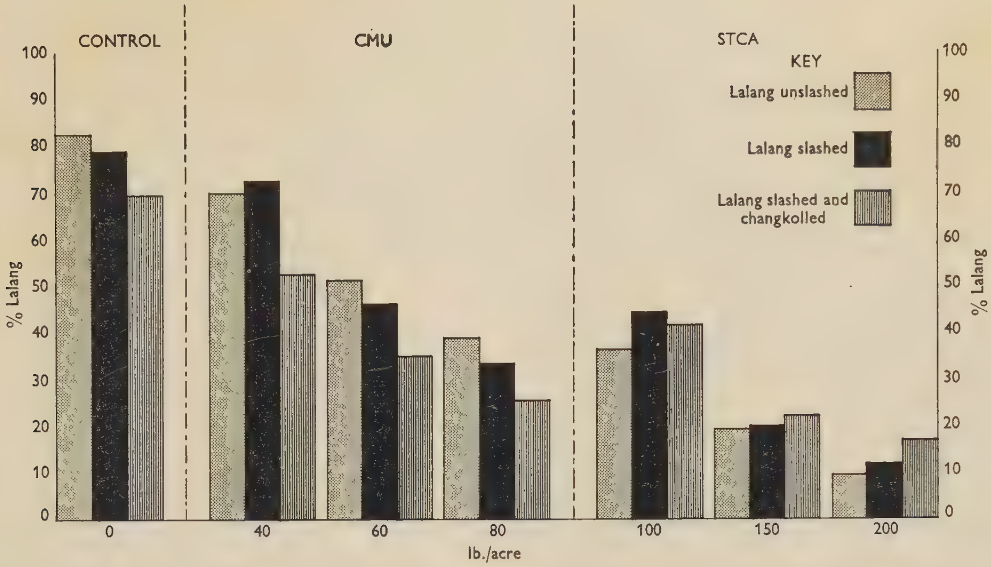


FIG. 1. Recovery of lalang six months after application of CMU and STCA in water at 100 gal./acre. Trials L1, L2, L5 and L6.

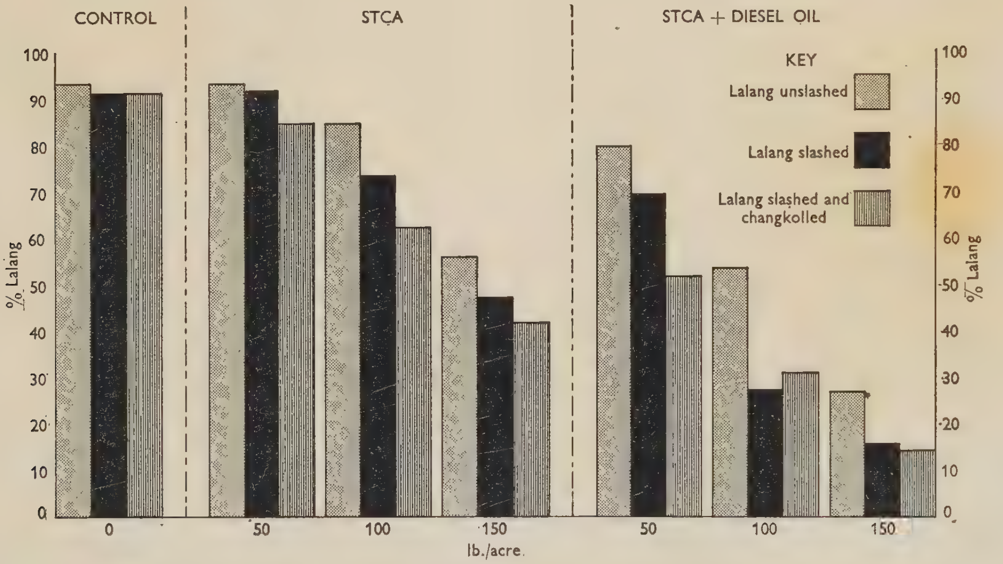


FIG. 2. Recovery of lalang six months after application of STCA in water at 100 gal./acre and in 50 gal. diesel oil plus 50 gal. water/acre. Trial L8.

using the new weedkiller 3-(4′-chlorophenyl)-1:1-dimethyl urea (CMU) at 20–80 lb./acre. The results were unimpressive, for only at 60 and 80 lb./acre was any appreciable (60–70%) reduction of the lalang obtained.

PROGRAMME OF EXPERIMENTS IN 1954

None the less the methyl urea derivatives as a group warranted detailed evaluation on such perennial grasses as lalang and bamboo grass (*Ischaemum muticum*), and to this end an extensive series of experiments was laid down in Malaya between February and April 1954.

The main lines of study embraced straight comparison at five centres of 3-(4′-chlorophenyl)-1:1-dimethyl urea (CMU), 3-phenyl-1:1-dimethyl urea (PDU), STCA, and a herbicidal oil formulation consisting of a 50 : 50 mixture of diesel oil and a petroleum aromatic distillate (Sovacide PYD). The CMU and PDU were 80% dispersible powders, and each was applied at rates per acre of 20, 40, 60 and 80 lb. in 100 gallons of water. Dosages per acre of STCA were 50, 100, 150 and 200 lb., also in 100 gallons of water. Sovacide PYD rates were 100, 250 and 400 gal./acre.

Superimposed at two centres were applications at different volumes: CMU and PDU were each sprayed at rates per acre of 20 lb. in 20 and 100 gallons of water, and at 40 lb. in 40 and 100 gallons; STCA doses of 75 and 150 lb./acre were each applied in 50 and 100 gallons of water.

Comparisons were also made at one centre of the effects of adding pentachlorophenol (PCP) at 3·6 lb./acre (as Kanex at 2 gal./acre) to CMU and PDU. In two trials STCA at 50, 100 and 150 lb./acre was applied in 100 gal. water and in 50 gal. water + 50 gal. diesel oil.

The influence of cultivation treatments on effectiveness was studied in all the main experiments, each chemical being applied alone or in conjunction with slashing and slashing plus changkolling.

In addition, phytotoxicity trials on rubber, oil palms and coconuts were an important part of the programme, and four months after the application of the chemicals three rubber seedlings were planted in each of the plots treated with CMU and PDU (40, 60, 80 lb./acre) and STCA (100, 150, 200 lb./acre) at Sagil and at Sungei Rinching estates.

In all trials the chemicals were applied as sprays by means of hand-operated Cooper-Pegler knapsack sprayers, but in one trial at United Patani estate CMU and PDU were applied also as granules. Frequent agitation was necessary with CMU and PDU to secure a good dispersion of the chemicals. The experimental programme is summarized in Table I.

TABLE I

DETAILS OF EXPERIMENTAL PROGRAMME

Location	Trial No.	Main comparisons
Glengowrie and Sungei Rinching Estates, Selangor	L1	CMU, PDU, STCA, Sovacide PYD
	L2	CMU, PDU, STCA, Sovacide PYD
	L3	STCA ± diesel oil
	L4	Volume of CMU, PDU, STCA
Sagil Estate, Johore	L5	CMU, PDU, STCA, Sovacide PYD
	L6	CMU, PDU, STCA, Sovacide PYD
	L7	CMU and PDU each ± PCP
	L8	STCA ± diesel oil
	L9	Volume of CMU, PDU and STCA
United Patani Estate, Kedah	L10	CMU, PDU, STCA and Sovacide PYD, including CMU and PDU in granules
	RP/1	Phytotoxicity—young rubber
Tulik Merbau Estate, Selangor	CP/BG/1	Phytotoxicity—coconuts, and herbicide trial on bamboo grass
Dept. Agric. Exp. Sta., Selangor	OP/1	Phytotoxicity—oil palms

The effect of chemicals on lalang was assessed by gradings of ground cover on a scale of 0–10, 0 indicating absence of lalang and 10 signifying complete ground cover. These assessments were made independently by the authors and their colleagues 4, 6, and 10 months after treatments. A mean for each sub-plot was calculated and the means were multiplied by 10 to give "percentage ground cover" figures, as will be seen on the accompanying histograms.

RESULTS ON LALANG

Main Comparisons

The results were disappointing so far as the newer chemicals were concerned. CMU did not achieve satisfactory control even after four months except at 60 and 80 lb./acre, and at the sixth month lalang regeneration was kept below 20% only by the highest rate. PDU was inferior to CMU: four months after application only 80 lb./acre plus preparatory slashing was really successful, but after six months no rate had kept regeneration of the weed below 20%.

The granulated form of CMU used in one trial (L10) appeared to be inferior to the dispersible powder formulation.

STCA, though ineffective at 50 lb./acre and only fair at 100 lb., gave excellent control at 150 lb. and 200 lb./acre. These effects were still very striking after six months, by which time Siam weed (*Eupatorium odoratum*), *Lantana camara* and sedges had invaded all STCA plots. In trial L10 on United Patani Estate the assessments made in January 1955, ten months after spraying, indicated that STCA was still holding its own, whereas on the CMU and PDU plots at rates of 80 lb. recovery of lalang was of the order of 30% and 40% respectively.

Single applications of Sovacide PYD gave poor results even at the very high rate of 400 gal./acre. Though all rates produced good initial effects on aerial growth, these were fleeting.

Typical results from four trials showing the recovery of lalang six months after application of some of the chemicals are shown in Figure 1. Regeneration between the 4th and 6th month (July and September) was 20% or less from all treatments and from the controls.

Subsidiary Comparisons

Slashing and changkolling slightly reduced the effectiveness of STCA at 100 lb./acre and above, whereas it tended to increase that of CMU and of PDU. Slashing alone and slashing plus changkolling alone had negligible effects on the growth of lalang except during a very brief period immediately after these treatments.

Volume of application was found in two trials to have little effect on the herbicidal activity of CMU, PDU and STCA on lalang, though marked differences were attributable to the amount of chemical per acre. In one trial CMU at 40 lb./acre following slashing and changkolling was decidedly more effective in 40 gallons of water than in 100 gallons, but in the second trial this difference was slight.

Nevertheless, from personal experience of the difficulties of application the writers have little confidence in volumes lower than 100 gallons per acre with the formulations and rates of CMU and PDU employed in these trials.

In two trials (at Sungei Rinching and Sagil) to compare the effects of applying STCA in water and in water plus diesel oil the superiority of the mixture was obvious. The application per acre of 100 lb. STCA in 50 gal. diesel oil plus 50 gal. water appeared to give slightly better results than 150 lb. STCA alone. Regeneration between July and September was also somewhat less with the mixture than with STCA alone. Recovery of the lalang after six months in the Sagil trials is shown in Figure 2.

Pentachlorophenol added at 3·6 lb./acre (as Kanex at 2 gal./acre) to CMU or PDU slightly increased the efficacy of the herbicides. Lalang foliage was killed more rapidly with pentachlorophenol than without it, but the effect was fleeting and it did not make the performance of CMU or PDU equal to STCA.

Phytotoxic Effects

Seedling rubber was showing no severe symptoms of phytotoxicity nine months after application of CMU, PDU and STCA: growth was affected only by CMU and PDU at 80 lb./acre and by STCA at 150 and 200 lb./acre. Two-year-old rubber at United Patani Estate suffered hardly any damage from CMU or PDU at rates up to 40 lb./acre within nine months of application, and at the end of this period CMU at 60 lb./acre had killed only one tree. STCA was comparatively harmless: even 200 lb./acre caused only slight terminal dieback on a single tree.

Coconut palms inspected six months after chemical treatment at Tulik Merbau showed no damage symptoms, but by the tenth month injury was showing on trees that had received CMU at 60 and 80 lb./acre and STCA at 150 and 200 lb./acre. Damage symptoms also appeared on one plot treated with STCA at 100 lb./acre and on one plot receiving 100 gal./acre of Sovacide PYD.

Mature oil palms inspected eight months after treatment were damaged by all rates of STCA, especially 200 lb./acre.

DISCUSSION AND CONCLUSIONS

Results of these trials were not submitted to statistical analysis because the grading system adopted in the assessments did not lend itself to statistical treatment. They cannot, therefore, be accepted as conclusive; but the trends are clear. Variations in the effects of treatments at the different centres were probably due to local differences in vigour of the lalang; in particular, the lalang of Sagil was much less vigorous than at Sungei Rinching and United Patani because of a fire which burnt all aerial growth about three weeks before application of the chemicals.

The high rates of CMU and PDU necessary to suppress lalang confirm a previous report from Malaya [1]. With an improved formulation of CMU, and with better coverage than was possible with the formulations under test, greater control could no doubt be obtained; nevertheless it would appear that lalang is moderately resistant to CMU.

Another rather surprising outcome was the relatively rapid regeneration of lalang at all sites following even the high rates of CMU. This is difficult to explain. On the light free-draining soil of Sagil Estate, and with the considerable rainfall in the six months after spraying, it can be assumed that leaching was greater than from the heavier soils at Sungei Rinching and United Patani. This should have resulted in better root kill at Sagil, though the more rapid leaching here might have helped to shorten persistence. Arguing from another angle, the rather heavy soil at Sungei Rinching should have retained the low-soluble CMU in the surface layers to deal with regenerating shoots and roots of lalang. Despite these different soil conditions, lalang regrowth following spraying was of the same rapid order at both Sagil and Sungei Rinching. One further possible explanation is that the lalang was merely checked—i.e. that it is moderately resistant to up to 80 lb./acre—and that the effect persists only until the "shock" wears off. Although the short persistence of effect of CMU is clearly indicated by these trials the cause remains unexplained.

The behaviour of the rubber seedlings in the plots treated with high rates of CMU, PDU and STCA should have indicated whether or not CMU and PDU were still present in the soil in early August 1954 when the seedlings were planted; unfortunately animal damage somewhat obscured the results of this part of the experiment, though seedlings removed from high-rate CMU and PDU plots and examined in the summer of 1955 seemed to be unaffected by any weedkiller residues that might have been present at the time of planting.

PDU was markedly inferior to CMU on lalang. As it is more soluble than CMU, and could therefore be expected to reach the roots more easily and completely, we assume that PDU is less toxic than CMU to this grass species. The neutral and sometimes negative effect of slashing and slashing plus changkolling on the effectiveness of STCA could possibly be explained by translocation of this chemical from foliage to roots so that removal of the foliage reduced the efficacy of the treatment. But general belief is that STCA is not translocated downward and that it is absorbed only by the roots. In 1953 the Agricultural Advisory Department of I.C.I. (Malaya) Ltd. had observed that STCA apparently worked more effectively on unslashed lalang. It is possible, therefore, that the aerial growth of the lalang acts as a catchment for the STCA and guides it down the shoot externally to the rhizome bud. Further, although application of STCA to slashed lalang may check growth efficiently it leaves the regrowth with little competition in contrast to standing unslashed lalang, which acts as a smother.

Indications from the two volume-comparison trials are that low volumes (20–50 gal./acre) are not appreciably inferior to high volumes (100 gal./acre). This point might be followed with some success when using STCA, but the CMU and PDU dispersible powders used in these trials do not lend themselves to application in low volumes of water, and neither dispersion in the water nor ground coverage of the spray is of a sufficiently high order for low-volume application to be considered practical.

The good results from mixtures of STCA in diesel oil and water are of technical interest only, for the chosen rate of 50 gallons diesel oil is uneconomic in Malaya, where a mixture of 100 lb. STCA and 50 gal. diesel oil costs almost as much as 150 lb. of STCA.

STCA at 150 lb. per acre emerges from these trials as the most practical treatment, giving excellent control of lalang for a considerable period. There are indications from previous observations that, under Malayan conditions, STCA persists in the soil only a few weeks and that two months after treatment with even 150 lb. of the chemical to the acre it should be quite safe to plant rubber seedlings. This possibility has not been confirmed in these trials owing to the partial failure of the seedling experiment; but a simple test would suffice to check the persistence of STCA.

The indications are that CMU and PDU at 60 and 80 lb./acre may be toxic to young rubber and coconuts. STCA was found to be toxic to coconuts and oil palms at 150 and 200 lb./acre, but it did not injure rubber at rates up to 100 lb.—at least up to nine months after application. Yet several instances have been recorded in estate practice of STCA at 150 lb./acre and over proving toxic to established rubber and showing a delayed action effect. It would be wise, therefore, to regard STCA as likely to damage rubber trees of any age when applied at rates of more than 50 lb./acre.

ACKNOWLEDGMENTS

Thanks are due to the managers, field officers and assistants of the estates upon which these trials were carried out for their willing co-operation in finding sites and helping with labour problems; to the Malayan Department of Agriculture for making available an experimental site at the Federal Experimental Station at Serdang; and to the Agricultural Advisory Department of I.C.I. (Malaya) Ltd. for their help and co-operation throughout the experimental series.

REFERENCE

[1] ANON. (1953). *Planters' Bull., Rubber Res. Inst., Malaya.* New Series No. 4, pp. 2–8.

BLOAT INVESTIGATIONS

W. S. Ferguson and R. A. Terry

Bloat is an important nutritional disorder of cattle and sheep grazing on legumes, though it can arise on grasses. It has been the subject of much research within the last few years, and it is now known that "frothy" bloat can be prevented by applying surface-active agents to pastures. This method, however, is likely to be uneconomic for general use, and further research aimed at eliminating the bloating power of growing legumes is needed.

Bloat of ruminants, usually associated with the grazing of legumes, is the result of an accumulation of fermentation gases in the rumen. The reasons for the interruption of the normal processes of gas elimination remain unknown. The disorder is found in many parts of the world, and research on its causes is equally widespread. Excellent reviews on the subject have been given by Cole *et al.* (1945) and Dougherty (1953). Johns (1954), reporting probably the first controlled systematic study of bloat in dairy cattle, also discussed the numerous theories on the cause of bloat.

Research on the problem of bloat was commenced at Jealott's Hill in 1946. Several lines have been followed, and this paper records the development and progress of the work.

EXPERIMENTAL WORK

The first aspect studied was the possible presence in bloat-provoking herbage of a substance which might interfere with the eructation mechanism, or rumen muscular activity, of the ruminant. Using lucerne rather than white clover to obviate complications with hydrocyanic acid, the presence of a substance capable of inhibiting the activity of isolated muscle was demonstrated (Ferguson, 1948). The substance was identified as the flavone tricin (Ferguson *et al.*, 1950). It was not possible to prepare sufficient tricin to investigate by animal tests any connection with bloat, but tests were made with quercetin, a flavone which has about the same muscle-inhibiting power as tricin. In numerous tests in 1949 and 1950 quercetin was administered as a drench or intravenously. The sheep and cattle received a variety of diets, and with sheep on winter ration potassium cyanide dosing was included. The sheep were confined to metabolism boxes, and 30–60 minutes before dosing they were fed either on hay and mangolds, young pasture containing 50% white clover, stemmy ryegrass, or lucerne. The drenches contained 0·5–2·0 g. quercetin with or without 0·1–0·175 g. potassium cyanide, but in one autumn test the sheep received 10 g. quercetin together with 2·5 l. lucerne juice. Intravenous injections contained 2·0–4·0 g. quercetin.

In these animal tests quercetin failed to cause bloat even under conditions very favourable for producing this disorder, and it must be concluded that if lucerne flavones have properties similar to quercetin they are unlikely to be involved in bloat production.

Attention was then directed to the possibility of tracing the causal agent, or agents, of bloat through the chemical fractionation of lucerne juice. In preliminary trials cattle were used as test animals, but it proved impossible to deal satisfactorily with the large volumes of liquid needed for the experiments. From work done in 1953 it was decided that sheep could be useful test animals. A flock of some forty cross-bred wethers were dosed early in 1954 with lucerne juice known to be bloat-provoking. Some fifteen of the wethers became bloated, and these were used in subsequent experiments.

The lucerne used for the fractionations came from a farm where bloat had been experienced. The juice was extracted by a roller mill, and for fractionation it was heated to 60° C to flocculate chloroplastic material. It was then filtered, cooled, passed through columns of ion-exchange resins and neutralized before being given to the sheep. Investigations were also made into the possibility that a bloat-provoking substance might be adsorbed on charcoal or precipitated with inorganic salts, peptides, etc., on treatment with 75% alcohol. These tests were made on selected sheep which were given 2–4 l. test solution by stomach tube in the early afternoon some 30–60 minutes after a grazing cycle ended. The degree of bloat was judged by eye 60 minutes after dosing.

The work showed that the bloating factor, or factors, was not associated with chloroplastic material in the juice; it was non-ionic and not readily adsorbed on ion-exchange resins—properties possessed by saponins, which have been suggested as a major factor in bloat.

Trials were therefore made by administering to sheep various saponins and foaming agents. Lucerne saponin was prepared from bloat-producing lucerne and doses of 22 g. in solution were given to sheep. Three wood saponins of the triterpenoid class and a commercial saponin (B.D.H.) were also tested in quantities up to 30 g. Sheep were also dosed with foam-stabilizers (Aphrosol FC, B.D.H., egg albumin) and with mixtures of grass juices, foam-stabilizers and sodium carbonate.

All these treatments failed to produce bloat, hence the materials were either less efficient foam-stabilizers than lucerne saponin or factors other than foam-stabilizers are involved in bloat production.

American work (unpublished) has suggested that household detergents might be effective in curing bloat. Tests were made on sheep, therefore, with a number of detergents (Daz, Tide, Teepol, Lissapol N, Lissapol C, Calsolene Oil HS) and also with the froth-breakers Avlinox (a polyoxyethylene derivative of ricinoleic acid) and Silicon DC550 (a polymerized methyl silicone), which are recognized as useful agents in curing "frothy" bloat. These were added to the bloat-provoking juices before dosing, and so the tests refer to the preventive rather than curative abilities of the materials.

No definite conclusions can be drawn from the relatively few results, but the detergents, at the quantities used, did not markedly influence the development of bloat. Foam-breakers, on the other hand, had a pronounced effect: doses of 3 ml. Avlinox prevented all signs of bloat, though 10 ml. did not entirely eliminate the trouble with a more effective juice; none of the sheep given Avlinox or Silicone developed more than slight bloat. Curative tests with foam-breakers were not undertaken, but one sheep which became dangerously bloated on treatment with lucerne juice was cured in 30 minutes by a 3-ml. dose of Avlinox.

It was thought that the sugar in lucerne juice might increase fermentation and gas production in the rumen, but the feeding to grazing sheep of large amounts of sugar showed that the animals can cope with any gas so formed.

Rate of flow of saliva into the rumen as a possible factor in the development of bloat was tested, using cow's saliva and a synthetic material. Neither influenced the severity of bloat.

As it is widely believed that placing the bloated animal in an uphill position helps to relieve the condition, tests were made in which sheep, after receiving lucerne juice, were positioned with their forefeet raised 12 in. and left thus for an hour. Results were not conclusive. In two tests raising the forelegs had little effect in relieving bloat, whereas in another two the effect was slightly beneficial. A single test with the hind legs raised gave no evidence of increase or decrease in the severity of bloat.

DISCUSSION

The sheep technique developed in the present work may give information on only part of the complex combination of factors producing bloat. Although gross individual variation was largely eliminated by the selection of relatively bloat-prone animals, it was evident that the state of fill of the rumen at the time of testing was of significance. Marked bloat occurred only when the rumen was "full," but it has not been proved whether or not the administration of a very potent material would produce bloat in an "empty" rumen.

Test dosing was done 30–60 minutes after the conclusion of a grazing period, and at this time the fill of the rumen was associated with the type of herbage grazed, at least during early summer and midsummer. On a pasture containing appreciable quantities of clover the sheep looked full; on an all-grass sward they were relatively empty.

It is unlikely that the intakes of dry matter and water by sheep grazing clover or grass pastures would be very different, and it is improbable that saliva secretion would differ sufficiently to account for the obvious variation in fill. It is felt, therefore, that the fullness of legume grazing is due to foam, probably stabilized and supported by constituents of the ingesta.

With cattle the state of fill at the time of ingestion of a bloat-provoking feed appears far less important, and cows relatively empty after a night's fast can develop bloat.

The dosage of lucerne juice to sheep was usually 2–2·5 l., administered after grazing into a full rumen, but even 4 l. did not make them look full. When on a clover pasture some slight discomfort and fullness was seen, but this disappeared within a few minutes. It seems that sheep could easily tolerate the volumes of liquid generally given in this work.

Despite failures to produce appreciable bloat in sheep by dosing with foam-producers such as saponins, egg white and Aphrosol FC, the efficacy of foam-breaking materials in relieving the condition strongly suggests that foam formation is the most important factor in lucerne bloat. Johns (1954) expresses a similar view with regard to red clover bloat and points out the presence of at least three foam-producing systems: saliva, saponins, and proteins and their breakdown products.

Clark and Weiss (1952*a*) have shown that roughages stimulate the flow of saliva, producing liquid ingesta which do not trap fermentation gas bubbles. They suggest that with succulent lucerne the flow of saliva is relatively low, giving rise to ingesta of a more viscous nature and a consequent tenacious foam. Johns (1954) points out that saliva is more likely to increase foam production in view of its low surface tension. The stability of the foam, however, is the significant factor, and it may be that some constituents of viscous ingesta are more efficient than saliva in this regard.

In laboratory tests, shaking lucerne juice with cow's saliva did not markedly affect frothing ability. In a single sheep test the administration of a considerable quantity of cow's saliva (750 ml.), together with 2·5 l. lucerne juice, certainly did not prevent bloat, but also it did not cause the bloat to develop to a degree necessitating remedial treatment. Further tests were made attempting to stimulate the flow of saliva by pilocarpine injections 30 minutes after sheep had been dosed with lucerne juice. The sheep remained well blown after 60 minutes but the test was inconclusive, since, although stimulation of saliva was efficient, much saliva dripped from the mouth. Further work is needed before the significance of saliva secretion in bloat production is elucidated.

There is no doubt about the frothing capacity of lucerne juice. In expressing the juice, the froth was frequently an embarrassment. It was permanent for many hours and held a considerable quantity of lucerne particles. Experience showed that the frothing capacity of the juice at preparation gave a fair indication of its bloating potential. Red clover juices, which were relatively innocuous, gave less foam and grass juices very little, although one grass sample taken from a field in which grazing cattle had developed bloat gave a strong foam.

At the present time it is not known whether the soluble and colloidal proteins, or other constituents, of fresh lucerne extracts appreciably supplement the frothing capacity of the saponins present. Lindahl *et al.* (1954) have produced bloat in sheep by administering saponin prepared from lucerne, but the quantity needed was far greater than the sheep could ingest at grazing.

Bloat-provoking herbages, legumes and occasionally lush young grass contain a high proportion of proteins, colloidal and soluble, and these may influence the physical condition of the ingesta. Bloat can develop 15–30 minutes after grazing begins, and the bloat-provoking principle must therefore diffuse out of the plant material rapidly. It seems doubtful if much of the ingested protein would be released from unchewed plant tissues within this time, and it is more likely that protein or protein degradation products in the rumen before the grazing of toxic herbage, rather than that in the grazed herbage, would supplement the stable foam of the soluble saponins.

Work on the fractionation of lucerne juice showed that juice freed of chloroplastic protein and passed through cation and anion exchange resins retained bloat-provoking properties. It seems unlikely that appreciable quantities of soluble protein and polypeptides would have escaped adsorption on the resins. With the sheep technique used, proteins in the test doses were therefore of little apparent importance, the main factor causing bloat being non-adsorbed and non-ionic, properties shown by saponins. The state of the rumen ingesta may have been of particular significance in these tests.

The present work was done on lucerne, since dosing animals with white clover juice introduces complications and dangers of toxicity from free hydrocyanic acid. White clover, however, is the most important legume in grazing practice in the United Kingdom and is responsible for the majority of bloat cases. The type of bloat arising on white clover varies from free-gas to frothy, the former probably preponderating, although substantial evidence on this is lacking.

It is open to doubt whether the two distinct types of bloat exist, and it is more probable that apparently different types differ only in the quantity of free gas trapped in the rumen, this being dependent on the stability of the foam (Weiss, 1953; Johns, 1954).

The most commonly used treatment for bloat is dosing with turpentine, with or without vegetable oil. Although turpentine may have muscle-irritating effects its true action is probably that of foam-breaking (Clark, 1948, 1950). Considerable success in relieving bloat has been attained with the powerful but non-irritating surface-active agents Silicone and Avlinox (Johns, 1954); Clark, 1950; Quin *et al.*, 1949; Singh and Rao, (1953). For the prevention of trouble Clark and Weiss

(1952*b*) have recommended the spraying of herbage, when it is most toxic, with these materials. Further experimental work along this line is needed. It should prove whether foam formation is an essential factor of bloat arising on various legume grazings and whether prevention, maybe at a relatively high cost at the moment, can be attained.*

Many methods of reducing the risk of bloat in grazing animals have been advocated—hay feeding, reduction of drinking, controlled grazing, wilting of herbage, etc.—but none is a certain preventive of bloat in susceptible animals grazing leguminous herbage at a particular bloat-provoking stage of growth.

It may well be that the eventual elimination of the bloat trouble will result from a better understanding of the part played by the soil on which the crop is grown. Although bloat incidence varies from district to district, apparently irrespective of soil type or fertility, some workers consider bloat to be more severe on fertile land, and Mississippi workers (Shawyer *et al.*, 1954) obtained increased bloat incidence on ladino clover heavily dressed with superphosphate and potash salts.

In many areas no bloat problem exists, and this is not due to a restriction of the pasture legumes. A factor in the chemical composition of the legume dependent on soil factors is evidently responsible.

Experimental work on the effect of soil treatments on the bloating properties of legumes should be profitable. Such work, properly controlled, would not be easy if grazing cattle are used as test animals, but useful preliminary work might be done on lucerne and red clover, using the sheep dosing technique described in the present paper.

SUMMARY

An account is given of experimental work carried out at Jealott's Hill on bloat.

Bloat was produced in dairy cows and sheep by dosing with lucerne juice. Sheep proved convenient test animals and were used in most of the tests described.

Parenteral and intravenous administration of the flavone quercetin, which inhibits the activity of smooth muscle, did not cause bloat even in the presence of cyanide. It is unlikely that flavones are concerned in bloat.

Fractionation of bloat-provoking lucerne juice showed that activity was retained after (*a*) precipitation of chloroplastic material and (*b*) passage of clear juice through an anion or cation exchange resin. This suggests that the bloat-provoking factor is non-ionic and not adsorbed on resins—properties shown by saponins.

Dosing sheep with lucerne saponins, four other saponins, egg albumin, and a synthetic foaming compound failed to produce bloat.

Two household detergents and a number of surface-active agents did not relieve bloat, but foam-breaking compounds were very effective.

A synthetic inorganic saliva and cow's saliva did not prevent bloat in sheep and from the single test made with cow's saliva it is not possible to say if it increased the severity of bloat.

It is concluded that the formation of a stable foam is a major factor in lucerne bloat and that food constituents, other than saponins, and the physical condition of the rumen ingesta probably influence the stability of the foam.

ACKNOWLEDGMENT

We thank the editor of *Journal of Agricultural Science* for permission to publish this much-condensed version of an article which appeared in Vol. 46, pp. 257–61, of that periodical.

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* Recent work has shown that bloat can be prevented by spraying bloat-provoking herbage, before grazing, with peanut oil or Avlinox.

REFERENCES

[1] Clark, R. (1948). *Onderstepoort J. Vet. Sci.*, **23**, 389–93.

[2] Clark, R. (1950). *J. S. Afr. Vet. Med. Ass.*, **21**, 173.

[3] Clark, R. and Weiss, K. E. (1952*a*). *J. S. Afr. Vet. Med. Ass.*, **23**, 163–5.

[4] Clark, R. and Weiss, K. E. (1952*b*). *Fmg in S. Afr.*, **27**, 282.

[5] Cole, H. H., Huffman, C. F., Kleiber, M., Olson, T. M. and Schalk, A. F. (1945). *J. Anim. Sci.*, **4**, 183–236.

[6] Dougherty, R. W. (1953). *J. Amer. Vet. Med. Ass.*, **122**, 345–52.

[7] Ferguson, W. S. (1948). *Nature, Lond.*, **161**, 816.

[8] Ferguson, W. S., Ashworth, R. de B. and Terry, R. A. (1950). *Nature, Lond.*, **166**, 116–17.

[9] Johns, A. T. (1954). *N.Z. J. Sci. Tech.*, *A*, **36**, 289–320.

[10] Lindahl, I. L., Cook, A. C., Davis, R. E. and Maclay, W. D. (1954). *Science*, **119**, 157–8.

[11] Quin, A. H., Austin, J. A. and Ratcliff, K. A. (1949). *J. Amer. Vet. Med. Ass.*, **114**, 313.

[12] Shawyer, C. B., Hogg, P. and Morrison, E. G. (1954). Quoted in *Mississippi Farm Res.*, **17**, (3), 1.

[13] Singh, G. B. and Rao, M. M. (1953). *Indian Vet. J.*, **29**, 543.

[14] Weiss, K. E. (1953). *Onderstepoort J. Vet. Res.*, **26**, 251–83.

BOOK REVIEWS

Capital in United Kingdom Agriculture Present and Future. S. Cheveley and O. Price. Pp. 54. The Netherhall Press, London. 1955. 2s. 6d. net.

To an economist, and nowadays to the general agricultural adviser, it is a most rewarding task to examine available resources on the individual farm and to assess the efficiency with which they are being used. When such an analysis is made it is seldom difficult to offer a plan or plans that will increase productivity and profit. Cheveley and Price in their valuable and thoughtful little booklet have done just this not for the single farm unit but for a much bigger enterprise—the National Farm of the United Kingdom—in other words, the agricultural industry.

Their conclusions confirm on a national scale what is only too apparent on very many individual farms. Fixed capital is seldom adequate to permit really efficient production of present output, much less of a substantial increase. Rents in comparison with alternative sources of income are too low to attract the new capital required. Further, particularly on the smaller farms, working capital is difficult to accumulate from farm profits quickly enough to keep pace with the inflation of present costs, quite apart from any attempt to finance the extra cost of increased output. On the other hand, to lower unit costs is essential if farm incomes are to be increased and subsidies reduced. Increasing output is often a most successful way of reducing unit costs and also a means to lighten the burden and difficulties of our balance of payments.

The authors stop short of pursuing the possible effect on a fully employed economy of creating the credit needed to increase farming capital or alternatively of suggesting those sectors of national expenditure which might be cut to permit of more resources moving into agriculture. Attention is concentrated instead on aspects which might lead to the best use on the farm of more capital if it were available.

There can be little disagreement with Messrs. Cheveley and Price that this country's main crop—grass—would well repay much more intensive management by effective grazing and improved conservation as prerequisites of substantial increases in livestock population. It is argued that at present prices milk supplies appear to be adequate, and although considerable quantities of both beef and mutton are imported, cattle and sheep are more likely to prove profitable with expansion and also to offer some prospect of saving foreign exchange. It might also be added that rising standards of living are usually reflected in a relative increase of fresh meat consumption. In the light of these suggestions a budget is presented to utilize the increased grass production through sheep and beef cattle together with a reduction in the quantity of imported feedingstuffs. The actual mechanics of calculations are not presented with any claim to precision in detail, but they are more than adequate to outline a rational policy of development for agriculture.

This book, small in size but vast in its implications, should be read and digested by all concerned with the well-being of agriculture. The analysis of the problems and the reasoning pursued deserve serious consideration, and the authors should be congratulated on the readable way they have surveyed the scene. Their eminently sound conclusions have been confirmed by the interpretation of a considerable mass of difficult statistical information, and this investigation is to be commended as an exacting but nevertheless a well worth-while piece of research work.

Whether or not progress towards the policy outlined should or could be effectively speeded up by preferential treatment for agriculture can only be decided by those responsible for fashioning and directing the economy of the nation as a whole. ARTHUR JONES

Rice and Crops in its Rotation in Subtropical Zones. E. Iso. Pp. 611, with line and half-tone illustrations. Japan FAO Association, Tokyo. 1954. Yen 3600 net.

Few people know more about the technique of rice culture than Dr. Eikichi Iso. He has devoted a lifetime to research on the crop in Formosa, his outstanding achievement being the breeding of the Horai variety, which not only greatly increased rice yields but, by facilitating catch cropping, added enormously to total productivity per acre in that sub-tropical island. Most of the results of Dr. Iso's researches have been published in Japanese, and it is gratifying that in this, his first book, he has made them available to a wider public by presenting them in English.

About half of the book is a detailed record of fundamental investigations into factors affecting rice production in Formosa. Every phase is covered. Varieties and their response to environmental factors take up about 100 pages, and cultural methods and general matters in rice production a further 200, including 60 pages on fertilizers and their application. The 253 tables of experimental results provide much material that the technical man often wants and seldom finds. The remaining portion, which has 187 tables and 33 figures, deals with crop rotation and land utilization problems. In Formosa two crops of rice are usually taken in the year, and the interval of 4–4½ months between them is used for catch cropping. How suitable crops can be grown and introduced in the rotation is explained very fully for sweet potato and flax (194 pages), with shorter accounts on wheat, buckwheat, tobacco, groundnut, maize, jute, hemp, castor bean, vegetables and green manures.

Illustrations are few, and more use might have been made of graphs. There is no index, but the contents are well classified and the tables are listed. The great defect of the publication, however, is its deplorable Japanese-English. The best that can be said for it is that the author takes pains to make his meaning clear, but everywhere there are phrases of this kind: "When they (insects) begin to stretch their fierce activities the rice plants just after transplanting will become their best prey"; and some passages are troublesome to read, as is this specimen from page 281: "What position the taste of Horai rice occupies in Japanese market, ranking which various kinds of market rice over there should be decided by the cooking examination, but a comparative experiment had even been made on the chemical ingredients contained in Horai rice and Japanese rice."

Nevertheless a book of this kind is wanted for its facts, which are plenteous, and those engaged in research on rice improvement will find much in it that they can profitably apply. The work is certainly the most comprehensive account ever to be published in English on rice production in any one country.

E. J. MCNAUGHTON

Inorganic Nutrition, Fertilisation and Soil Amelioration for Lowland Rice. Shingo Mitsui. Pp. 107, with line illustrations and colour frontispiece. Yokendo Ltd., Tokyo. 1954.

In the summer of 1952 Professor Mitsui of Tokyo University gave a course of lectures at an F.A.O. training course in India; the present slim volume is based on these lectures, revised and supplemented. It is therefore not a comprehensive textbook on its subject, but it gives particulars of various special lines of investigation with which the author or other Japanese workers have been associated. Brief accounts and abstracts have made the Western world aware that valuable work on rice soils and manuring has been done in Japan in recent years: much of this work is brought together and presented here.

There are two main parts: (I) Inorganic nutrition of lowland rice, and (II) Some characteristic properties of the paddy soil, its amelioration and fertilizer placement. Nitrogen, as the most mobile and fugitive of the major plant foods, receives most attention; phosphate and potash are also discussed; but little is said about the micro-elements apart from iron (which is important in connection with the behaviour of sulphur compounds). The radioactive-tracer technique has been used in studying both nitrogen and phosphate nutrition. Nitrogen fixation by blue-green algae is discussed, but its practical application appears to be of doubtful value.

Particular attention is given to degraded (heavily leached) paddy soils, which can give rise to "akiochi" or fall-down disease of rice. This trouble arises from poisoning by the H_2S that is liberated in waterlogged soils if they are deficient in available iron compounds. In such soils the use of sulphur-containing fertilizers requires especial care, and sulphate of ammonia and superphosphate are being replaced to some extent by urea, ammonium chloride, and fused magnesium phosphate. About one-sixth of the paddy soils of Japan are affected.

The time and method of application of nitrogenous fertilizers are also discussed, with experiments; the best system is to apply a part of the nitrogen (using sulphate of ammonia) on the furrow slice shortly before the field is harrowed and flooded, prior to transplanting; the remainder of the nitrogen is put on as a top-dressing (or in the form of "ball fertilizer" thrust into the mud), two or three weeks before the earing of the crop.

Misprints and other errors are rather frequent, but excusable; the index is hardly adequate, and the text should be searched for further information. None the less, because of the importance of its subject-matter the book can be strongly recommended to anyone making a serious study of paddy soils and the nutrition of the rice crop. H. L. RICHARDSON

Organic Insecticides. Their Chemistry and Mode of Action. L. Metcalf. Pp. x + 392. Interscience. 1955. 68s. net.

The author opportunely reviews the position at a stage when "over 100,000 organic chemicals" have been screened for insecticidal action and "more than 100" are in commercial use.

The chapter headings are mainly chemical; chapters on nicotine and related compounds, on the rotenoids, and on pyrethroids are followed appropriately by one on joint action of insecticides, with a general treatment of synergism; and chapters on organic thiocyanates, dinitrophenols, DDT, acaricides, BHC, cyclodienes, organic phosphorus compounds, carbamates and miscellaneous compounds lead to a concluding chapter on insect resistance. Each chapter dealing with a group of chemicals has sections on relation of structure to toxicity, mode of action and mammalian toxicity. As a result, a far-ranging subject is given order, and generalities begin to appear. The 1220 literature references reach peaks of 204 for the DDT chapter and 210 for phosphorus compounds. Published information on the chemistry and mode of action of the cyclodienes is still meagre.

Although "much remains to be learned regarding the chemistry and mode of action of insecticides, the relation of their structure to toxicity, their metabolism in plants and animals," this book, by its detailed and imaginative presentation of factual information and informed speculation, will play a valuable part in linking the compendia of the past with enlightened textbooks on the subject that have yet to be written. The hallmark of the latter may well be found in the inclusion of tentative paragraphs, or even a chapter, on new insecticides whose properties have been accurately predicted.

The standard of printing is high and few errors were noted. On page 97, line 9, the sense needs clarification, and on page 220, line 8 from bottom, a statement could be challenged. C. C. TANNER

ABSTRACTS

CROP PRODUCTION

Forms of potassium in the soil. L. Wiklander, *Potassium Symposium, Zürich*, 1954, 109–17.

The content of exchangeable potassium in mineral soils is usually less than 1% of the total potassium, whereas in organic soils it represents most of the total potassium. About 1% of the exchangeable potassium is present as ions in soil water, the rest is adsorbed on the soil particles and rapidly replaceable by neutral salts; it is easily available to plants. Fixed potassium, bound between the basal planes of minerals in the positions normally occupied by K^+ as a lattice constituent, is a transition form between the exchangeable potassium and the lattice potassium of illite and the micaceous minerals. By leaching and weathering, part of the lattice potassium close to the particle surface is removed and substituted by other ions; on addition of potassium, K^+ migrates back into these positions, thus rebuilding the lattice and becoming fixed. NH_4^+ and $H_3O^+(H^+ + H_2O)$, having similar size and valency to K^+, counteract fixation; Na^+, Mg^{++}, Ca^{++} and Ba^{++} do not compete with K^+ for the interlayer positions, but may increase fixation by raising the *p*H.

S.F.A.

The absorption of potassium by the plant. A. C. Schuffelen, *Potassium Symposium, Zürich*, 1954, 169–79.

The process of ion absorption is divided into two parts: one part depends on the energy supply of the plant for the accumulation of ions, the other part is connected with the supply of the ions by the soil. Activity on the root epidermis depends on the activity of a particular ion in the medium, on the relation of this ion to the other ions, and on the e.m.f. between root and medium, but is independent of the kind of medium (solution, suspension, soil). The activity of an individual ion can only be determined approximately, but the relative activities of the ions can be measured exactly. The K/Mg ratio in soil solution increases with the moisture content of the soil. In experiments with artificial soils it was found that the selectivity coefficients for K and Ca, determined in young oat plants, were 0·3, 1·0 and 1·4 respectively for high, moderate and low K/Ca activities, supporting the carrier theory rather than the surface theory. The carrier theory was also supported by the selectivity coefficients for K and Na determined in abscised oat roots.

S.F.A.

The determination of potassium requirements by visual symptoms and plant analysis. T. Walsh, *Potassium Symposium, Zürich*, 1954, 327–47.

Potatoes on potassium-deficient soil were sprayed with KCl at sowing, at the onset of mild deficiency, or when marked symptoms had developed. In all cases the plants recovered from the deficiency symptoms, but the differences in yield were highly significant, showing that by the time symptoms are recognised it is too late to apply potash in order to obtain an economic return. Other limitations to the use of visual symptoms are the complicating effect of other elements and the occurrence of spontaneous recovery by cereals, associated with secondary root development. A major difficulty in plant analysis is the obtaining of a suitable sample. Figures for wheat growing under good nutritional conditions showed an overall range of 0·74–3·02% potassium in dry matter over a period of six weeks. For plant analysis to be of value a rigid scheme of sampling is necessary, taking into account the type of plant, the organ of the plant, the maturity, and the season. The interpretation of results is complicated by the interaction of other elements. Also it must be recognised that, for grassland, management and plant competition have as much effect on the potassium content of herbage as does the level of soil potash.

S.F.A.

The chemical composition of cocksfoot S143 at successive stages of growth as influenced by fertilizer treatment. I. Effect of nitrogen fertilizer on proximate composition. D. H. Parish, W. E. Coey and K. L. Robinson, *Res exptl Rec. Minist. Agric. N. Ireland* 1952–3, 1955, **3**, 46–54.

A randomized block design with three replications was used in the experiment. Cocksfoot was sown in the summer of 1949, and all plots were treated with an NPK fertilizer at 4 cwt./acre. On 24th April 1950 half the plots were dressed with 'Nitro-Chalk' at 5 cwt./acre. Cuttings were made at weekly intervals over a six-week period from 8th May. At the first cut the grass was about 6 in. high and leafy; at the sixth and final sampling it was 15–18 in. high at early flowering stage. Percentage D.M. was significantly higher at all cuts in grass from low-N plots; yield of D.M. was increased by nitrogen treatment, and this increase, significantly higher at latter stages of growth, amounted to 10 cwt./acre at the final sampling; both percentage and total yield of crude protein were increased significantly at all stages of growth by nitrogen application. In grass from both high-N and low-N plots the percentage crude protein decreased with maturity. No differences were shown in the crude fibre values, but ether extract was significantly higher at all stages of growth on high-N plots. The effect of 'Nitro-Chalk' on ash composition is to be discussed in a later paper.

E.M.A.

Effect of the nitrogen, phosphorus, potassium and magnesium nutrition of potato plants on the content of free amino-acids and on the amino-acid composition of the protein of the tubers. E. G. Mulder and K. Bakema, *Plant and Soil*, 1956, **7**, 135–66.

Certified seed potatoes of the varieties Noordeling and Voran were planted on sandy or peaty soils poor in N, P, K, or Mg; the potato plants were dressed with different amounts of the element in which the soil was deficient and optimum amounts of the other nutrient elements. The free amino-acids and amino-acid composition of the protein in the tubers were determined by a paper-chromatographic method. The protein content of the tubers was found to be increased by ample N or deficiency in P, K or Mg, but the amino-acid composition of the protein was unaffected by N, P or K (no figures given for Mg). The amino-acid composition of the soluble non-protein fraction was much more variable. Conditions which increased the nitrogen content of the tubers (ample N, deficiency in P or K) increased the proportion of asparagine, glutamine and arginine in the non-protein fraction. The tyrosine content of the non-protein fractions was markedly increased by K deficiency, which is in agreement with earlier observations that K-deficient potatoes are liable to enzymatic blackening.

S.F.A.

Production of early grass. A. H. Charles, *J. agric. Soc. Univ. Coll. Wales*, 1955, **36**, 57–63.

Three strains of timothy were sown with white clover in a trial laid down at Aberystwyth in 1952. The relative yields on 26th March 1954 were: Bd 2502, 100; S48, 111; S50, 153. The S50/white clover, even when grazed as late as 12th October 1953, produced 1000 lb./acre of dry matter with 20% crude protein content. Several trials were carried out in which perennial ryegrasses (S23, S24, Irish) Italian ryegrasses (S22, Irish), a hybrid ryegrass (HI), tall fescues (S170, Alta) and a meadow foxtail (S55) were compared. S22 was markedly superior to HI in the second and third harvest years and showed more vigour in cold springs. In the first harvest year there was little difference between the two tall fescue strains and their yield was only about half of that of S22, but in the second harvest year S170 was markedly superior to Alta and gave about 3½ times the yield of S22. The yields from ryegrasses and meadow foxtail cut on 4th April 1952 were considerably greater than the sum of the yields after cutting on 10th March and 4th April.

S.F.A.

CROP PROTECTION

The persistence and fate of DDT on foliage. II. Comparative rates of loss of DDT deposits from glass plates and growing leaves. J. Ward and P. E. Burt, *Bull. ent. Res.*, 1955, **46**, 849–68.

Measurements of the comparative rates of loss of crystalline deposits of pure p,p′-DDT on leaves and on glass showed that the main cause of the loss is the volatility of the DDT. The loss of toxicity resulting from foliar penetration of DDT is too small to be of practical importance. At low temperatures (10–21° C) suspension deposits applied at 2 μg. per sq. cm. lost about one-third in 37 days on both leaves and glass plates. At higher temperatures (15–35° C) deposits were lost more rapidly, and more from plates than from leaves. In both series the insecticidal activity of the deposits on plates, but not on leaves, was greater than was to be expected from the amount of DDT remaining. It was recommended that for maximum persistence the insecticide should be used at its maximum practical rate, since the lower the rate at which DDT is applied the greater is the percentage lost in a given period.

D.L.

Methods of treating sorghum selfing bags for insect control. R. G. Dahms, J. B. Sieglinger and W. D. Guthrie, *J. econ. Ent.*, 1955, **48**, 568–72.

Paper bags used on sorghum heads to ensure self-fertilization provide an ideal environment for the maize leaf aphid (*Rhopalosiphum maidis*) and the corn earworm (*Heliothis armigera*). DDT impregnated at a rate of 133 mg. per bag gave excellent control of *H. armigera* but caused an increase in the number of aphids. Heptachlor, aldrin, dieldrin, lindane and Metacide also gave good earworm control, and toxaphene was effective at 290 mg. per bag. BHC, lindane, heptachlor, aldrin, TEPP, and demeton gave satisfactory control of *R. maidis*. Both BHC and lindane were found to cause high sterility of the sorghum heads, whereas this defect was not apparent with aldrin or with heptachlor. Bags used six months after impregnation lost little toxicity, and bags impregnated with 0·5% aldrin were still effective after two years. D.L.

Ecology and control of carrot rust fly. D. S. Maclagan, *Res. Bull. West Scot. agric. Coll.*, No. 12, 1955, 32 pp.

In field experiments on the control of the carrot fly, *Psila rosae*, single applications of 10% DDT dust or 4·5% crude BHC dust at 0·75 oz./10 yards of drill did not give complete protection when the infestations were heavy. Two applications of DDT gave increased yields without causing taint. A single foliar application of BHC at 1·66 oz./10 yards increased yields four times, but caused taint. Threefold increases, without tainting, were given by a single seed-bed application of BHC at 1·22 oz./10 yards. Seed-dressing with γ-BHC at 3·5% of seed weight gave fourfold yield increases with no taint. D.L.

Effects of calcium sulfamate and sodium sulfanilate on small grains and on stem rust development. A. Acosta and J. E. Livingston, *Phytopathology*, 1955, **45**, 503.

Two applications of calcium sulphamate to cereals at a rate of either 9 or 12 lb./acre, the first when about half of the plants had pollinated and the second a week later, markedly reduced the germination of wheat and oat seed but only slightly reduced that of barley. The effect on yield and grain weights was somewhat variable. Wheat yields were increased in three out of four treatments and that of oats in half of the trials. Stem rust, *Puccinia graminis* f. sp. *tritici*, was substantially reduced on each crop. Applications of sodium sulphanilate a week after tillering and six days after blooming resulted in significant yield increases, and stem rust was again controlled. D.L.

Relation of soft rot development to protective barriers in Irish potato slices. W. J. Smith and H. F. Smart, *Phytopathology*, 1955, **45**, 648–54.

In the U.S.A. potatoes are usually transported or stored shortly after harvest at a temperature of about 40° F. After removal from this temperature they often rapidly develop bacterial rot, caused by *Erwinia atroseptica*. *In vitro* trials with tuber slices have shown that the development of suberin and periderm, sufficient to act as a protective barrier against the entry of the organism, is associated with storage at higher temperatures. Barrier development was most pronounced on slices held at 70–80° F, which were the highest temperatures in the experimental range. Slices held for 4 days at 50° or 60° developed barriers equal to those in slices held for 2 days at 70° and 80°. Slices held at 40° developed little suberin and no periderm in 4 days. Barrier development varied with the potato variety: it was most rapid in Irish Cobbler and least in Mohawk. Slices held for 2–3 days at 70° or 80° before inoculation with *E. atroseptica* developed much less decay than did those held for 1 day, and those held for 4 days were unharmed by subsequent inoculation. Decay was not inhibited on slices that had been held at 40°. D.L.

Pentachloronitrobenzene for control of clubroot of crucifers. M. E. Gallegly and C. F. Bishop, *Plant Dis. Reptr*, 1955, **39**, 914.

Pentachloronitrobenzene (PCNB), mixed in the top 4 in. of soil by rotary tiller at rates of 20–40 lb./acre, tripled broccoli yields in plots infected by the clubroot organism *Plasmodiophora brassicae*. Equal results were obtained when transplants were watered at ½ pt./plant with a solution of 2 lb. PCNB/100 gal. water. Clubroot was not eliminated by these treatments, but most plants developed excellent fibrous root systems with only a few small clubs at their extremities, and such plants gave normal yields. D.L.

Zinc-deficiency of *Hevea brasiliensis* as a predisposing factor to Oidium infection. E. W. Bolle-Jones and R. N. Hilton, *Nature, Lond.*, 1956, **177**, 619–20.

Glasshouse studies in Malaya have shown that a relationship exists between the susceptibility of *Hevea* rubber trees to attack by *Oidium heveae* and the zinc status of the plants. Symptoms of zinc deficiency appeared on plants three months after sowing in sand with a zinc-free culture solution, and from the sixth month onwards the plants became severely infected with *O. heveae*. Plants grown on complete nutrients, and copper- or molybdenum-deficient plants, showed only feebly developed colonies of the disease organism. D.L.

Filipin, an antibiotic effective against fungi. A. Ammann, D. Gottlieb, T. D. Brock, H. E. Carter and G. B. Whitfield, *Phytopathology*, 1955, **45**, 559.

A new antibiotic has been isolated from cultures of *Streptomyces filipensis*. Named filipin, it is an unsaturated substance of the conjugated polyene type. It has a wide antimicrobial spectrum, and is also active against fungi. The following minimum concentrations (g./ml.) were required for *in vitro* kills within 72 hours: *Aspergillus niger*, 3·9; *Fusarium oxysporum* f. *dianthi*, 7·8; *Helminthosporium sativum*, 7·8; *Penicillium digitatum*, 3·9; *P. notatum*, 31·0; *Rhizoctonia solani*, 500·0. Crude filipin did not affect the germination of pea and tomato seeds at concentrations up to 100 g./ml. Grey leaf mould of tomatoes, caused by *Stemphylium solani*, was reduced by 25% when plants were sprayed with crude filipin in methanol at a rate equivalent to 415 g./ml. of pure filipin. No phytotoxic effects were observed on the tomato at this concentration. D.L.

Sources of inhibitors of barley false stripe virus infection. J. T. Slykhuis, *Proc. Canad. phytopath. Soc.*, 1956, (23), 21.

Juices from leaves of *Capsicum frutescens*, *Chenopodium album* and *Monolepis nuttalliana*, in 1 : 20 dilution, completely inhibited the development of false stripe symptoms in barley. Juices from *Salsola pestifer*, *Solanum tuberosum* and *Fragaria* sp. were sometimes successful, but usually caused only partial inhibition. *C. frutescens* caused a high degree of inhibition in dilutions as high as 1 : 200. Skim milk was also successful, but showed a marked decline when diluted to 1 : 40. Cultural filtrates from many fungi also inhibited the establishment of the virus. D.L.

Experiments on the control of the potato-root eelworm by trap cropping with black nightshade. R. D. Winslow, *Plant Pathology*, 1955, **4**, 139–40.

Root leachings from vigorously growing plants of black nightshade (*Solanum nigrum*) stimulate larval hatching of the potato-root eelworm *Heterodera rostochiensis*, although not to the same extent as do diffusates from potato roots. This suggested the use of black nightshade grown as a trap crop, and field trials were conducted. Egg-larvae populations in 1952 were reduced 23% on a sandy clay loam, and by 60% on black fen soil, when oats were undersown with nightshade. In 1953 nightshade without a nurse crop gave 40–50% reduction, but in 1954 nightshade made little growth and there was scarcely any reduction in the eelworm population. Trap cropping with nightshade was concluded to be an uneconomic proposition, especially if the weed was grown to the exclusion of a normal crop. D.L.

Terramycin and plant growth. A. G. Norman, *Agron. J.*, 1955, **47**, 585–7.

Critical tests were initiated to investigate claims, made in the popular press in America, that terramycin acts as a plant growth stimulant. In laboratory studies elongation of primary roots of cucumbers was inhibited by 5–10 p.p.m. terramycin; at lower concentrations there was no evidence of growth stimulation. Root growth in barley was inhibited by 2·5 p.p.m. terramycin; root weight was reduced by about 40% but higher concentrations of the antibiotic did not effect substantially higher reductions. Greenhouse trials were carried out using soils of high and low fertility, vermiculite, and sand. Test crops were maize, oats, barley, and soya beans. Watering with terramycin at 10 p.p.m. concentration caused no significant difference in emergence or on seedling size. Field trials were carried out over a 2-year period on maize and soya beans, plantings being made by hand to ensure complete uniformity. Treatments compared sowing seeds dry, after soaking in water, and after soaking in a 10 p.p.m. terramycin solution; also sprinkling untreated seed with water or with a 10 p.p.m. terramycin solution either once or three times after sowing. In the first season emergence and early vigour (7–10 days after planting) of maize were favourably affected by watering terramycin; survival rate after 14 days was not. Although the number of larger seedlings was increased, yields of maize were not. On the basis of the results it is thought that the growth stimulation by terramycin, claimed in earlier work, was due solely to the protective antibiotic action against non-specific root pathogens. E.M.A.

MCPA for the control of weeds in spring oats. J. G. Elliott, *Agriculture, Lond.*, 1956, **62**, 574–7.

Field trials over the last five years have shown that the accepted period for spraying spring oats with MCPA, viz. between completion of tillering and starting of shooting, can be safely extended. Applications of the sodium or potassium salts of MCPA as low-volume solutions in water can be made at any stage of growth between the expansion of the first leaf and the beginning of shooting. Occasional deformed heads and a slight reduction in yield in a weed-free crop were obtained irrespective of the time of application. Annual weeds, including some classified as moderately resistant to MCPA, were controlled more successfully when the application was made while the oat crop was in the 1–4 leaf stage than when it was made at the normal time with oats in the 6–7 leaf stage. In 1954 experiments successful weed control at either time of application did not increase yields; but in 1955 earlier control of weeds resulted in greater yields. It is suggested that, owing to the variation in spring weather, the time of annual weed emergence relative to the growth of the oat crop is not constant, and it is important that the correct time to spray should be judged according to the density and age of the weed population. M.M.W.

The stability of dalapon in soils. B. J. Thiegs, *Down to Earth*, 1955, **11**, (2), 2–3.

A sensitive analytical method was used to investigate the effects of moisture, temperature and organic matter on residual quantities of dalapon (sodium 2,2-dichloropropionate) in the soil. The method involved the extraction of the compound from the soil, removal of interfering substances and hydrolysis to pyruvic acid, which was then estimated colorimetrically as 2,4-dinitrophenyl hydrazone. Dalapon decomposed most rapidly in warm soils, and at 50 p.p.m. in soil it generally disappeared in 2–4 weeks. The compound was relatively stable at low temperatures in moist soil and at high temperatures in dry soils. The rapid disappearance of dalapon from soil after an initial "lag" period of a week or more, and the more rapid disappearance of fresh additions of dalapon to treated soil, indicated that a bacterial population capable of utilizing the compound is built up. The breakdown of dalapon by soil micro-organisms thus appears to be similar to that of 2,4-D. M.M.W.

New leads from recent field research with dalapon. L. Southwick, *Down to Earth*, 1955, **11**, (3), 6.

Further experiments with dalapon (sodium 2,2-dichloropropionate) have shown that fallow treatment of grass weeds can be carried out either in the late autumn or spring. Dalapon is rapidly decomposed by micro-organisms in warm moist soil, and it has been found that soil treated with dalapon at 8–10 lb./acre can be planted four weeks later with maize, potatoes, small fruit and vegetables without adverse effects on yield. On perennial grasses, split applications, such as two or three doses at 5 lb./acre, were more effective than a single treatment of the equivalent rate. Control of both broad-leaved and grass weeds has been obtained by dalapon combined with hormone weedkillers, but contact weedkillers tend to reduce the effectiveness of dalapon. Field trials have shown that although most crops are sensitive to dalapon it can be used satisfactorily on sugar cane and as a basally directed spray on maize, cotton and fruit trees. M.M.W.

ANIMAL HUSBANDRY

Fattening of cattle: a comparison of indoor winter fattening with summer fattening on grass. J. Morrison and others, *Res. exptl Rec. Minist. Agric. N. Ireland*, 1952–3. 1955, **3**, 90–7.

Sixteen Shorthorn bullocks were purchased in the autumn and divided into three groups for the trial. Group I consisting of 5 animals was fattened indoors on silage fed at 122 lb./head daily for 11 weeks beginning on 16th December. Group II, also comprising 5 bullocks, was fattened from 16th December on silage, first fed at 56 lb./head daily and later at 70 and then 75 lb., with the addition of hammer-milled oat sheaves, initially fed at 6 lb. but later increased to 9 lb./head daily, together with hay fed to appetite. Group II was fed the experimental rations for 14 weeks. Group III of 6 bullocks was outwintered on a rough field supplying foggage and was given access to an open shed where silage was available, though not sufficient for maintenance, and also oat straw to appetite. Towards the end of the wintering period swedes were also fed and the animals were fattened on grass from 26th March to 6th July. Average daily gains in lb. were: Group I, 2·40; Group II, 1·85; Group III, 2·43. Details of estimated costs and returns for the different methods of fattening are shown, the highest profit arising from Group III, followed by Group I. E.M.A.

The effect of chopping and lacerating before ensiling on the digestibility of silage by cows and steers. C. C. Balch, J. C. Murdoch and J. Turner, *J. Brit. Grassl. Soc.*, 1955, **10**, 326–9.

The three silages were prepared simultaneously from a timothy/meadow fescue sward. The herbage for the chopped silage was cut into lengths of 2–4 in.; the laceration process was more severe. The composition, digestibility and nutritive value to cows and steers are tabulated. The chopped silage was in general more digestible than the unchopped, while the values for the lacerated silage were intermediate; these differences were apparently due to varying losses of nitrogen-free extract during ensiling. The agreement between the digestibility coefficients for cows and steers was good. The mean starch equivalent of the dry matter, calculated from the content of digestible nutrients, was 45 in the control, 47 in lacerated silage and 50 in chopped silage. S.F.A.

Winter fattening of bullocks: grass silage compared with arable crop silage. J. Morrison and others, *Res. exptl Rec. Minist. Agric. N. Ireland*, 1952–3. 1955, **3**, 98–105.

Feeding value of grass silage made from a 4-year ley having a composition 21% D.M. with 13·9% C.P. was compared with pea-oat crop ensiled with molasses at 2 gal./ton green material. The pea-oat silage contained 17·8% D.M. with 15·5% C.P. Ten bullocks (Shorthorn or Shorthorn × Ayrshire) were used in the trial and were fattened indoors on 70 lb. silage together with 6 lb. bruised oats/head and good-quality hay to appetite. During the experimental period, lasting from 5th February to 5th May, the animals were weighed at fortnightly intervals. Group I on grass silage made an average daily gain/head of 2·05 lb. Group II on pea-oat silage made 1·33 lb. At slaughter the animals of Group II did not grade so well as those of Group I, and financial results suggest that the use of arable crops for silage is unprofitable. E.M.A.

Studies on resistance to *Trypanosoma congolense* developed by zebu cattle treated prophylactically with Antrycide pro-salt in an enzootic area of East Africa. M. A. Soltys, *Ann. trop. Med. Parasit.*, 1955, **49**, 1–8.

At the Central Trypanosomiasis Research Laboratory at Tororo in Uganda the author studied the acquirement of immunity by zebu cattle against *T. congolense* and the influence upon this of repeated injections of Antrycide pro-salt. Three groups each of six zebu cattle, which came from a district free from trypanosomiasis, were kept in a fly area for 28 months, during which period they were given 14 injections of Antrycide pro-salt (10 c.c. at two-monthly intervals). The three groups were then handled differently. Group A was kept on in the infected area for a further 18 months, during which period the Antrycide injections were continued. Group B was also kept in the same infected area but received no further injections of Antrycide. Group C was moved to a fly-free area for 10 months and then returned to the infected area. At the same time a fourth group of untreated control cattle was placed in the infected area in order to indicate the degree of exposure to infection. All five animals in this control group contracted *T. congolense* infection. Three were treated successfully with Antrycide methyl sulphate, but the other two, which were allowed to go untreated, died from the effects of the infection after 53 and 85 days respectively. None of the cattle in groups A, B and C contracted trypanosomiasis, i.e. they had become immune to infection. In immunological studies it was found that these immune animals had not developed much neutralizing or protective antibody and only to a very slight degree complement-fixing antibodies. The untreated control animals also failed to develop neutralizing or protective antibodies but did develop complement-fixing antibody. J.T.E.

Control of pasture-acquired infections of *Nematodirus spathiger* and *Haemonchus contortus* in lambs with phenothiazine-salt mixture. J. H. Turner and M. L. Colglazier, *Amer. J. vet. Res.*, 1954, **15**, 564–73.

Two similar trials on pasture during two successive grazing seasons were carried out to test the efficacy of a 1 : 9 phenothiazine-salt mixture against combined natural infections of *Nematodirus spathiger* and *Haemonchus contortus*. A total of twelve lambs were employed in each trial. Lambs were grazed on parasite-contaminated pastures with one group receiving the medicated mixture, the other having access to salt only. A control group of comparable lambs was also maintained on a comparatively parasite-free pasture. Lambs on medication consistently displayed lower degrees of parasitism, better weight gains, fewer abnormal stools, and higher hematocrit levels than untreated lambs on contaminated pastures. Furthermore, untreated lambs on comparatively parasite-free pasture made even greater weight gains than did the treated lambs on contaminated pastures. No fatalities occurred in either the medicated groups or in the untreated control group on clean pasture, whereas two died and another was killed *in extremis* in the unmedicated groups on contaminated pastures. Weekly faecal egg counts indicated in some lambs with mixed infections that the *H. contortus* not only reversed the normal self-limiting course of *N. spathiger* infections but caused exacerbation and prolongation of nematodirosis. The results of these tests suggest that the phenothiazine-salt regimen is of some direct value in the control of *N. spathiger*, and particularly beneficial when coexistent *H. contortus* infections are present. [*Authors' summary*]

An experiment on the cumulative efficacy of phenothiazine-salt mixture against *Nematodirus* and *Haemonchus* in lambs during a second grazing season. M. L. Colglazier and J. H. Turner, *Amer. J. vet. Res.*, 1955, **16**, 558–62.

This is a sequel to a previous report by these authors, and it concerns the third year of a trial during which the experimental conditions were the same as before. Results were similar to those obtained in the first two years, but the benefit of the continuous treatment with phenothiazine was more marked in terms of degree of parasitism, weight gain, and general bodily condition and condition of the blood. The authors believe that this improved result was a cumulative effect of the long-term treatment which brought about a progressive decontamination of the pastures during successive seasons. The specific control by phenothiazine over *Nematodirus* was plainly in evidence, since, during the whole of the trial, five out of eight untreated sheep on contaminated pasture died of the effects of the parasitic infestation, while none of the treated animals suffered even ill effects from what was originally similar parasitism. J.T.E.

Effect of phenothiazine on conception rate in sheep. R. L. Blackwell and R. W. Allen, *Amer. J. vet. Res.*, 1955, **16**, 563–4.

The authors have found no positive evidence on the point in question in the literature, though a few suggestions have been made. They therefore set out to determine whether a full curative dose of phenothiazine given to ewes one day before the start of a breeding season has any influence on conception rate, etc. The dosage used was 25 g. of green phenothiazine. Half the 96 ewes in the research project were artificially inseminated and the rest mated naturally. It was found that phenothiazine treatment showed no detrimental effects on the occurrence of oestrus, conception to first service, total pregnancies during the breeding season, or frequency of twinning. J.T.E.

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